SOILS AND CROPS

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SOILS AND CROPS

BY

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PREFACE

"Soils and Crops" is a companion book to "Live Stock and Farm Mechanics." It is the purpose of these two books to present the material in agriculture that is essential in the elementary schools. New subject matter is constantly being discovered in this field, and it is with pleasure that the author brings much of this new material to the boys and girls of our country schools, many of whom will never go to college or even to high school.

Some one has recently said that the purpose of teaching and learning agriculture is to get the facts and principles essential in economic production and efficient marketing of agricultural products. It will require only a brief examination of the Table of Contents or of a few chapters to see that much of the new material now available has been incorporated in this book and the former volume, "Live Stock and Farm Mechanics."

The production of crops in different countries has been briefly mentioned. More and more should we study and learn about the yields from a world standpoint, for no one can judge or predict the future prices of products unless he surveys the facts and conditions from an international viewpoint.

This book, like the other, presents a rather wide range of agricultural topics and hence is adapted to any state of the Union. In the teaching of agriculture, fundamental principles, with sufficient concrete data to substantiate the principles, should constitute the material of the course, and these principles are the same the world over.

The best schools subscribe for several good agricultural papers, and pupils should summarize one article relating to the work

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weekly. Bulletins applicable to the subjects being studied may also form the basis for pupils' reports.

The Laboratory Exercises and Home Projects suggested at the close of each chapter constitute a very important part of the course. Fifty or sixty Exercises should be completed in a year and should be written up under the following headings:

1. Object
2. Materials used
3. Procedure
4. Conclusion

Each Exercise may be followed by application questions made by the teacher.

Each school should organize one or, possibly, two boys' clubs and girls' clubs and teacher and pupils should consult with their state leader in order that their school may get all the benefits accruing from club work.

The author desires to express his obligations to Jeptha Riggs, Professor of English in the Cape Girardeau State Teachers College, for reading the entire manuscript and making helpful suggestions; to Perl Stella Gehrs for much help in connection with the graphs and for other work in the preparation of the manuscript; and to others to whom acknowledgment is made elsewhere.

JOHN H. GEHRS.

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CAPE GIRARDEAU, MISSOURI.
February 2, 1924.

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PART ONE

SOILS

Courtesy of International Harvester Co.

The new way of harvesting wheat

SOILS AND CROPS

CHAPTER I

THE SOIL — ONE OF OUR BEST FRIENDS

Land conditions affect the life of people. — The earth is a wonderful place, because it is the home of plants, animals, and man. Three fourths of the earth's surface is covered by water; only one fourth is left as man's habitation. The land as a home for man is the basis for the study of the various phases of industrial, commercial, and place geography. The history, the industries, the commerce, and the habits of the people of every nation have all been influenced and controlled largely by the physical features and climatic conditions of the land. The industries and commerce of every section of a country is predetermined largely by the geographical features and the agricultural resources found in that section.

The soil provides the necessities of life. — Air, water, and soil, very common elements, are essential to plant and animal life. We can not do without air; in fact, if air is withheld for a minute, death would ensue. Water is also a necessity, although it is said man can live a week or ten days without water. The soil provides the materials out of which food, clothing, and shelter are made. Some nations and communities are manufacturing communities and nations; they manufacture articles and exchange them for food products. These nations would soon suffer from famine and succumb to death, were it not for the fact that they get foods from other sources.

The famines of the earth are the result either of the failure of the soil to produce foods or of the indolence of the people in producing and distributing it. Famine-stricken areas often have the finest soil and the best of climatic conditions for plant growth; yet the people can not or will not produce enough for their own

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Fig. 1. — Products of the soil

Animal life, vegetable life, and building materials — all are products of the earth's bounty.

sustenance. What these people need more than anything else is a public-school system and a government which extends justice to all. Ideas and ideals are essential to every people, and a prayer for self-improvement and self-enlightenment along the line of getting ideas and ideals is a more important prayer than one which is a request for food and clothing and shelter. The purpose of missionaries of the world is to bring salvation to the people

among whom they do missionary work. But in addition the good missionary will bring his people into the knowledge of producing, preserving, and using the best products of the soil (Fig. 1).

Pope, in his "Essay on Man," gives us the following bit of good advice — we might well memorize it —

> "If vain our toil,
> We ought to blame the culture, not the soil."

The soil is clean and full of life. — The soil is clean and contains millions of bacteria per cubic foot. These bacteria are our friends, just as plants are our friends. And just as plants require air, water, a reasonably warm temperature, and food for growth, so do bacteria in the soil require all of these essentials for growth, and they use them when we provide the best conditions for plant life.

Exhausted soils in the United States. — There are over 10,622,000 acres of abandoned farm lands in the United States according to a report made by The National Conservation Commission, and about 4,000,000 more which have been devastated by soil erosion. The states in the Appalachian Mountain region have been hardest hit by wasteful practices. Large areas from Pennsylvania to Georgia, and westward, including portions of Kentucky, Tennessee, Alabama, Missouri, Louisiana, Arkansas, Mississippi, and North and South Carolina, have been abandoned. In fact, all states of the Union have abandoned farms. Soils are not wholly exhaustible; but from a standpoint of economic production, many soils have long ceased to yield profitable returns. It is fortunate indeed that weeds, grass, and trees begin to reclaim the land, as soon as man abandons it. We feed animals before they starve; but we handle the soil as if it would never get hungry.

A bank account with the soil. — Hopkins, in "Soil Fertility and Permanent Agriculture," says: "It is the business of every farmer

to reduce the fertility of the soil by removing the largest crops of which the soil is capable; but ultimate failure results for the landowner unless provision is made for restoring its productiveness. Every farmer should adopt a system of farming that is

Fig. 2. — Terraced farm land in South Carolina

Erosion is prevented and soil fertility is maintained by a series of terraces.

permanent — a system under which the land becomes better rather than poorer."

It is certain, if plant foods are constantly taken from the soil and nothing returned, that the soil will sooner or later become exhausted. There are nine mineral elements needed by plants. These elements are phosphorus, potassium, calcium, magnesium, iron, sodium, silicon, chlorine, and sulphur. Some of these

are found in soil in great abundance, while others may be almost wanting. It is not necessary to add those that are already plentiful in the soil; but it is necessary to replace those that have been taken away. Every farmer should keep a bank account with

Courtesy of International Harvester Co.

Fig. 3. — Result of adding lime to a clover field

One can usually tell when the soil needs lime by the kind of vegetation that it produces. When the legumes do not grow well, but moss and red-colored weeds and grasses thrive, it is a sign that lime is needed.

his soil and should feed his soil in order that it may in turn feed him.

Nations fall when the soil fails. — There are many things essential if a nation is to live and prosper. Good schools, good churches, good families are all very essential to a nation. When

any of these decay, it is certain that the government itself is endangered.

One of the contributing causes of the downfall of the Roman empire, of the Athenian government, and of various other nations, which have come and gone, was an unresponsive soil. When foods are not provided, discontentment, robbery, and civil wars ensue. A hungry people can never do well. Starvation and national prosperity can not prevail at the same time.

Just as nations have gone the road to decay, so often individual farmers and, occasionally, whole communities have fallen because they did not look well after the one thing from which they derive their prosperity — the soil.

Towns and villages found in agricultural communities are never prosperous, unless the farmers of those communities are prosperous. And when the farmers prosper, it is evidenced by good roads, good homes, well-improved farms, and thriving villages, towns, and cities.

Profits on the farm.— There are many essentials for making a profit on the farm. Two of them are applicable to the lesson we are studying, and a third is important enough to deserve consideration in any discussion of farm profits. The first two things essential to making a profit on the farm depend upon the soil, while the third one depends upon the selling price of the farmer's products and the cost of the commodities the farmer buys.

1. Crop yields bear an important relation to profits. Large yields at a low cost of production are essential to success in any kind of farming. In order that the farmer may be able to get large yields at low costs, he must have reasonably large fields in which he can use machinery with efficiency; his land must be fertile and productive; and the price, or money value, of his land must not be too great, otherwise the cost of production will

at once be advanced because of interest and taxes which high-priced land must support.

2. Grain farming can not be very successful over a long number of years for it finally destroys the fertility of the soil. But live-stock raising helps much in protecting the fertility of the

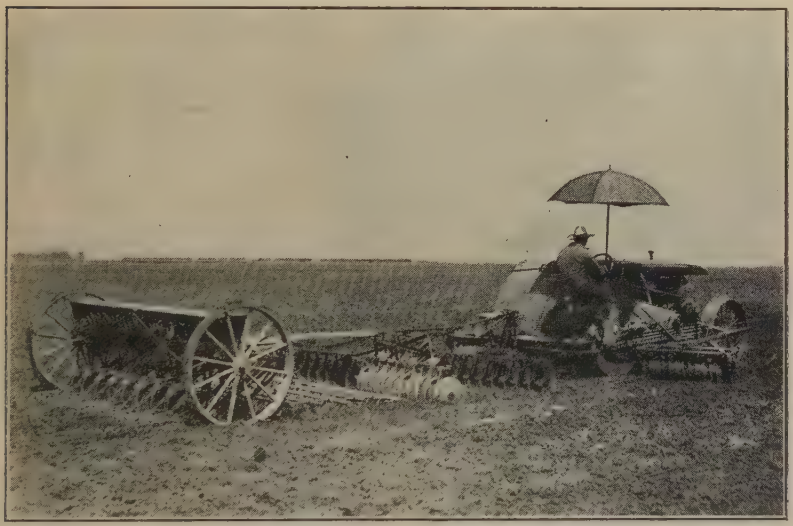


Fig. 4. — Efficient use of machinery in Minnesota

Where fields are large and level, the tractor has made possible the performing of many operations at one time, thus saving man labor and lowering the cost of production.

soil (p. 72). The whole story points in this direction: in order to have a profitable cycle in farming, we must have a fertile soil so that plants and animals may be produced efficiently.

3. The third essential which has an important bearing on profits is not at all dependent upon a fertile soil, but relates to the prices the farmer receives for his products and the prices he has to pay for the commodities he purchases.

The prices received by the farmer since 1913 for his products and the purchasing power of his commodities when he bought anything are shown in the following table:

Year	What the Farmer Received for His Products (Per cent)	What He Had to Pay for 32 of the Commodities He Bought (Per cent)
1913	100	100
1914	112	103
1915	106	104
1916	89	123
1917	106	190
1918	112	218
1919	111	231
1920	86	218
1921	67	124
1922	69	130
1923	72	132

In 1913 a farmer could take $100 worth of products and buy in return $100 worth of tractors, seeds, shoes, hats, or foodstuffs. But from 1913 to 1923 the price of farm products dropped, while the commodities which the farmer had to buy remained much higher.

It is very essential that the prices on farm products be on a parity, or level, with the prices of other commodities. Only on this basis can the farmer make a profit. The low prices, or the shrunken dollar of the farmer, from 1919 to 1923 caused many farmers to go bankrupt. Mortgages had to be met; and owners of farms lost thousands of dollars in not being able to sell their products for more than half price, and then being compelled to buy machinery, clothing, and foodstuffs at a very high price.

Summary. — The earth is the home of man, and the soil is one of his best friends. When the soil is depleted, plants can not be produced, and starvation and death are sure to follow. It is well enough therefore to keep a bank account with the soil. We must feed the soil before it gets hungry so that in turn it may feed us and save us from getting hungry. Individual farmers, whole communities, and even nations prosper as they husband the soil; and they fail in direct proportion to the extent to which they suffer the soil to be depleted and neglected.

If the farmer is to prosper, he must receive prices for his products which are on a level with the prices he must pay for the commodities he must buy. We are all mutually interested in the prosperity of every class of people in the United States, because it is impossible to sell products to any people unless they have money with which to buy. The farmer can not long endure if he gets only 72 cents on the dollar for his products and is compelled to pay $1.32 for the commodities he must buy.

LABORATORY EXERCISES AND HOME PROJECTS

1. Discuss in an essay this topic: How one farmer by depleting the fertility of the soil has low crop yields and how another farmer by maintaining the fertility of the soil has high crop yields.

2. Discuss the topic: The farmer should receive for his products prices which are on a level with those he pays for the commodities he buys.

3. Answer these questions: (1) What does the farmer get for 100 pounds of wheat, and what does he have to pay for 100 pounds of flour? (2) What is the price of fat hogs on foot, and what does the butcher charge for pork? (3) What does the farmer receive for wool, and what does a woolen suit which contains $3\frac{1}{2}$ pounds of washed or 7 pounds of unwashed wool cost?

Note to the Teacher: All laboratory work should be neatly, carefully, and systematically recorded in a well-kept notebook. It may be desirable to write up each exercise in the usual way, namely, the object of the exercise, the materials used, the procedure or operation, and the conclusion. A loose-

leaf notebook 8 × 10½ inches will be found most satisfactory. Notebooks should be uniform in size.

Lists of free bulletins from your Agricultural College and the United States Department of Agriculture should be written for, and the bulletins received should become a part of the permanent school library. Bulletins should be classified and those on the same topic should be bound together by punching holes in the proper place and tying.

CHAPTER II

SOIL-FORMING AGENCIES

Origin of soils. — A long, long time before man appeared, the earth was a molten, gaseous mass, "without form and void" according to Biblical story, but it was gradually cooling off and becoming harder. This cooling, gaseous mass was composed of water and the various rocks now found in the earth. As it cooled, it solidified. The process of solidification caused the earth to shrink. This is the reason the earth's surface is elevated in some parts and depressed in others, causing mountains, hills, and valleys.

This solid mass, although broken in many places by the shrinking of the earth, was nothing but fire-burned rock. Sandstone, limestone, granite, quartz, and other kinds of rocks were to become the chief foundation of our soil. The breaking down of the sandstones is responsible for our sandy soils. Clay soils are due to the decomposition of feldspar and mica, both of which are a type of granite. Limestone soils are made largely from limestone and generally contain small quantities of silica (sand) and iron compounds. The iron compounds give clay soils their reddish and yellowish color. The kind of soil depends to a large extent upon the kind of rock from which it was originally made.

This chapter will discuss the agencies that originally aided in making the soil and the value of these agencies in the building of the soil to-day. The chief agencies in the formation of soil are: (1) water; (2) plants; (3) animals; (4) winds; and (5) weathering.

Water as an agency in forming soils. — Water in the form of a liquid and a solid is the most potent agency in soil formation. The various kinds of streams, from rivulet to river and ocean current, are constantly changing the surface of the earth. We are told by geologists that the bed of the ocean is becoming more level daily because of the movement of water, which carries over sediment. Likewise, the earth is being leveled. Streams of water moving over the land produce much friction on the surface over which they are traveling. This friction and the dissolving qualities of water break up and wear down rock particles. Many acres of land have been formed by alluvial deposits. In fact, all lands along streams, bottom lands, the coastal plains, the soils at the foot of mountains and hills have been formed to a large extent by moving water. The hillsides are impoverished, and the bottoms are enriched. The impoverishment of hillsides should be prevented by systems of farming and by farm management that prevent soil washing (Fig. 6).

Fig. 5. — The soil augur is used to determine the character of the soil and subsoil

The tides of the ocean, the waves of the lake or pond are constantly changing the contour of the coast or land line.

Water percolating through the soil and through the rocks dissolves and helps to disintegrate the rocks and rock particles of

Courtesy of International Harvester Co.

Fig. 6. — Effect of erosion on fertile land

In a few years the soil fertility and usefulness of fine land may be thus destroyed. Tree crops will often preserve valuable land that would otherwise be ruined by washing.

the soil. The cement that binds together the particles of sand of the sandstone is dissolved, and the rock crumbles into a sandy mass. Some of the limestone effervesces in the presence of water, dissolves, and forms a powdery mass. All rocks are affected more or less by percolating water.

Vegetation is aided in its decay by the presence of a proper amount of water. When plants are placed in a dry place or in water, they decompose very slowly, but at the surface of the earth a proper amount of water is usually present, so that the plant that was grown this season may decompose and change its organized system into a disorganized form. Thus the plant of one generation may use the plant foods the plant of the preceding generation has stored in its own body. What a wonderful friend water is to man! Three fourths of the earth's surface is covered by water; seventy-five to ninety per cent of green vegetable life is composed of water; about fifty per cent of the bodies of animals is composed of water; and the rounds, or cycles, of life are aided by water (p. 39).

Water with changing temperatures is a wonderful agent in the formation of the soil. It expands about one twelfth upon freezing. For this reason a bottle or pipe bursts when the water content freezes. Rocks are broken asunder by this powerful agent, and soils are formed. Not only should we think of freezing water in breaking up the original rocks, but we should also think of its ameliorating effects upon all soil that is frozen through and through every winter since time began. Farmers rather welcome severe freezing winters. A thorough freezing of the water in the soil is valuable, like the addition of a small quantity of manure to the land.

Glaciers ages ago were a great factor in forming the soil. These slow-moving ice sheets mashed and ground the rocks and carried a lot of vegetation with them — all pulverized — forming soil. Some of the best soil of the world is of glacial and alluvial formation. (See Fig. 7.)

Plants as agencies in forming soils. — The effects of plants on soils are of three kinds; namely, (1) physical, (2) chemical, and (3) bacteriological.

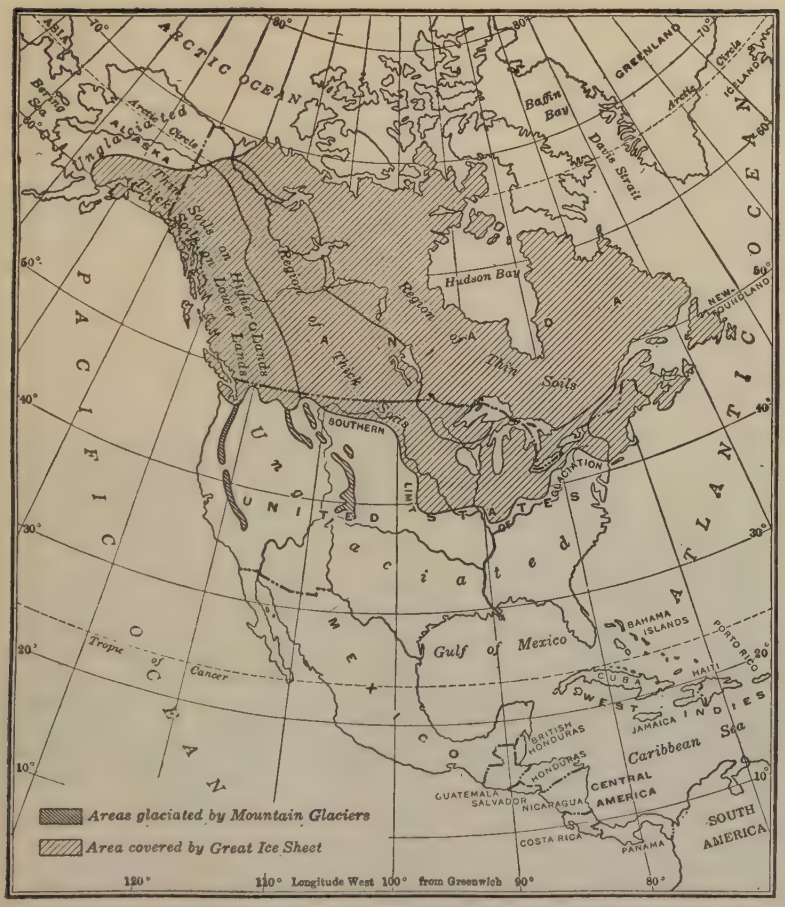


Fig. 7. — Glacial map of North America

1. *Plants aid in forming the soil physically.*—In the beginning plants affected to a large extent the parent rock, but at present plants affect the soil itself to a greater extent. In the beginning plants cleaved rocks and broke them apart, and this method of forming soil is still going on.

Rocks and cliffs have been separated, sidewalks have been torn up, and stone walls have been turned over by the roots of growing plants. Marks have been left by growing lichens upon the hardest tombstones found in the cemetery. Trees with their deep-penetrating roots, the grasses with their shallow-growing roots, the legumes with their nodule-forming roots — all have had, and will continue to have, a wonderful physical effect upon the mother earth (Fig. 9).

Not only in cleaving the rocks and soils have plants had a wonderful effect in soil formation, but roots, stems, and leaves upon decomposition have added organic matter. This matter makes the humus, which is a large part of the soil.

Beat into sand particles a fifty-pound sandstone rock, powder into dust a fifty-pound limestone rock, and add to this fifty pounds of organic matter; mix these three components thoroughly and you will have a fairly good soil — not subsoil, but soil. For as soon as you add organic matter to the beaten sandstone and pulverized limestone, you convert it into soil materials out of which subsoils are made. Soils that contain much organic matter are lighter and much more easily worked than when the humus is lacking. If you want a soil to plow easily, get a lot of organic matter into it — this gives it lightness and such a fine tilth that it is easily workable. Thus plants both in the process of growth and in the process of decay change the physical characteristics of soil (Fig. 8).

2. *Chemically*, the soil is enriched by decaying organic matter. Every plant that decays adds to the soil all the elements that were needed for its growth. The chemical composition of the corn plant is given on p. 40. The composition of other forms of plant life are more or less similar.

Although plants do not add the ingredients in the same proportion, because different plants have different compositions,

yet in general they add the ingredients they need in their own growth.

If a pound each of soil, water, and manure (organic matter) are mixed together, the character of the water changes. The water

Courtesy of International Harvester Co.

Fig. 8. — Turning under a green-manure crop

This is one of the most economical and efficient ways of maintaining and increasing the fertility of the soil.

and the ingredients in the organic matter mix, and this mixture acts more vigorously upon the hard rocks than water does alone. The discolored water takes out some of the mineral compounds in the rock soil particles and prepares them in a soluble form for plant growth. The chemical changes in the soil due to the

presence of humus are highly essential in making plant foods available for further plant growth.

Cultivation, fallowing the soil, and dry hot weather are conducive to an excessive loss of humus in the soil. Every precaution in the way of keeping a soil mulch, covering the soil with green-manure crops, and preventing it from drying out should be employed in conserving humus, the most wonderful of all plant foods.

Peaty or marsh soils made by decaying vegetation in ponds and lakes is composed of about twenty per cent of humus. Arid lands often have less than two per cent, and the average field in the Corn Belt has about five per cent humus. A few years of careless soil management may reduce this chemically important plant food materially; so the productive acreage capacity of the land is reduced from five to ten dollars.

Courtesy of International Harvester Co.

Fig. 9. — Sweet clover root showing nodules

3. *Bacteria*, which are very necessary to plant growth, feed upon the organic matter in the soil. Clover, alfalfa, soy beans, cowpeas, and other legumes do not do well in some soils, but as soon as the soil is inoculated with proper bacteria the plants thrive. The nodules on the legumes are caused by specific bacteria. Fig. 9 shows the nodules on the root of sweet clover.

From three to fifteen million bacteria have been found in a gram of soil. They live to the greatest extent in the surface foot, where plant foods in the form of organic matter exist. The changes wrought upon organic matter by the bacteria in the soil are very important, and the function of these little organisms in the soil can not be overemphasized. Hence conditions conducive to their growth should be preserved or provided. The conditions for their growth are: (1) food; (2) proper temperature; (3) proper amount of moisture; and (4) proper amount of air. Plants then are important agents physically, chemically, and bacteriologically in the formation of soil.

Animals as agencies in forming soils. — Earthworms consume soil for their food. The soil thus used is broken down and disintegrated to a considerable extent. The openings they leave in the soil affect its physical condition. Darwin estimated that earthworms carry about one inch of soil to the surface of the ground in England every five years. Ants, gophers, ground squirrels, and badgers improve the soils they dig up.

The manure voided by animals is one of the largest factors in keeping up soil fertility. The proper care of manure should be considered for its importance in soil formation. Much soil fertility is shipped to the cities by way of live stock. The return of the waste materials in the form of commercial fertilizers must sooner or later become a practice if our land fertility is to be maintained. The slaughter houses must in the future become more serviceable in returning fertility to the farmers at reasonable prices, for, after all, it is a mutual service.

Wind as an agency in forming soils. — Wind-formed soils are important in some sections of the United States. In some of the Western States the winds have taken away the depth of the plowed soil and carried it elsewhere. Cover crops are often grown to protect the soils from the winds.

Weathering of soils. — The heat of summer and the cold of winter and the ever changing temperature from season to season, and from day to day, are important factors in forming soils. The weathered rocks may be seen along the roadside. The crumbling banks along roads and streams are an evidence of weathering. Rainfall aids in this process.

Summary. — The chief agencies in the formation of the soil are water, plants, animals, winds, and the weathering processes. We should look upon most of these agencies as our helpers. However, running water and winds may do a lot of damage to the soil. It is important that we know how to make the best use of plants, animals, and weather conditions in order that they may render us more service in maintaining and improving soil fertility.

LABORATORY EXERCISES AND HOME PROJECTS

1. Take the class to a cliff if possible to observe and discuss how the water helps in breaking down the outcropping rocks. What kind of soil is being formed from the rock observed?

2. Have pupils on their way to and from school observe the different ways in which plants help in forming soil. Write up this Exercise in the usual form.

CHAPTER III

TEXTURE OF SOILS

The soil. — The soil is the richest agricultural heritage of all ages. Upon it and its fruitfulness everything else is dependent. The mines, the factories, and the commerce of the world would soon stop, and our cities would crumble to dust, were it not for the fact that the earth continues to respond constantly to the hands and the intelligence of man. Let the earth withhold her yields for one year, and a gloom of sorrow, and even death, would result. For these reasons we should diligently study the soil; how to maintain its fertility and by better practices to make our people more prosperous, prepared, and peaceful.

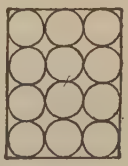


Fig. 10. — Pore space of sandy soil

Pore space is proportional to size of particles.

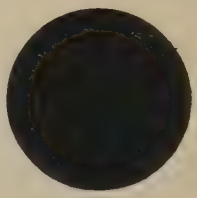
Texture of soils. — The texture of soils refers to the size of the soil particles. The texture of a coarse sand is coarse; that of clay is fine; the soil particles of clay soils are the smallest of all. The comparative measurements and names of soils in the table on p. 24 are based upon the size of the soil particles.[1]

Clay soil particles are microscopic. One sand particle two millimeters in diameter, if crushed and ground to the size

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: samples of clay; fine and coarse sand; tall glass bottles, test tubes, or graduates; two one-quart tin cans and, if possible, tall glass tubes (1 inch × 3 feet).

[1] Bureau of Soils, United States Department of Agriculture.

of the finest clay particle, would make thousands of such particles.

Name	Measurement	Relative Sizes
Fine gravel	1 to 2 millimeters	
Coarse sand	0.5 to 1 millimeter	
Medium sand	0.25 to 0.5 millimeter	
Fine sand	0.10 to 0.25 millimeter	
Very fine sand	0.05 to 0.10 millimeter	
Silt	0.005 to 0.05 millimeter	
Clay, less than	0.005 millimeter	

Soils named according to texture. — Soils are named mostly in accordance with their texture. The structure and color also are considered; but for our purpose here we shall consider texture alone as a basis for naming soils. The percentage of coarse sand, clay, and silt determines what name shall be applied. If sand predominates, then it is a sandy soil; if clay, it is a clay soil; etc. The table on the opposite page gives a fair idea of the composition of six principal types of soils.

How the texture of the soil may be modified. — The texture of the soil may be modified by the addition of organic matter. This does not reduce the size of the original soil particles; but since the particles of the organic matter are much smaller, it reduces the average size in sandy soils. The addition of organic matter to sandy soils and the resulting change in soil texture

increase the water-holding capacity, lessen air circulation, and hasten chemical changes in the soil.

COMPARISON OF SIX TYPES OF SOILS BASED UPON TEXTURE

	Clay (Per cent)	Clay Loam (Per cent)	Silt Loam (Per cent)	Fine Sandy Loam (Per cent)	Sandy Loam (Per cent)	Coarse Sand (Per cent)
Clay	50	35	20	15	15	5
Silt	30	42	60	30	20	10
Very fine sand	12	15	10	25	15	10
Fine sand	5	5	6	20	25	30
Medium sand	2	2	2	5	10	25
Coarse sand	1	1	1	4	10	15
Fine gravel	0	0	1	1	5	5
Total	100	100	100	100	100	100

The texture of clay soils and of loam soils is affected in the opposite direction. They are made looser by the addition of organic matter, and the passage of air and water is increased by the addition of organic matter. Clay soils that plow heavily may be made to plow much more easily if sufficient organic matter is added.

Relation of size of soil particles to water-holding capacity. — Coarse sandy-soil particles have much less surface area than do the particles of clay soils. Cutting a cubic inch of soil into four equal cubes doubles the surface area. The film water a solid cubic inch could hold is one half as much as the same block would hold if it were cut into cubes one-half inch each way. But if a cubic inch of rock were crumbled into a thousand soil particles, the surface area would be increased many times, and the amount of film water it is capable of holding would be in direct proportion to the additional surface exposed. Clay soils will hold much

more water than sandy soils. The water-holding capacity of a coarse sandy soil, a clay, and a humus soil is approximately as follows:

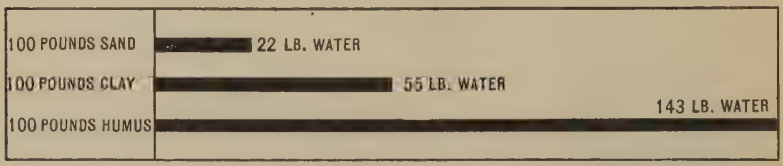


Fig. 11. — Water-holding capacity of different types of soils

It has been estimated that the surface area of a cubic foot of clay-soil particles is 150,000 square feet, and that the surface area of the particles of a cubic foot of coarse sand is 40,000 square feet. From this it is apparent that a clay soil holds more capillary water than does a coarse sandy soil. It is also evident that an inch of rain falling upon a clay soil does not wet it so deeply as the same amount of rain wets sandy soil.

Pore space in soils. — Sandy-soil particles afford less pore space than do clay soils (Fig. 11). Large particles have small pore space. Small particles have large pore space.

If a small soil particle were placed between four large particles, the open pore space would be closed to some extent. If a dozen soil particles were placed in the same open space, the open pore space would become very small.

Water passing through soils, or percolation. — A heavy rain readily passes through a coarse sandy soil, but it will percolate through a clay soil very slowly. Water passes through a clay soil so slowly that the top layers soon become saturated to such an extent that the surface begins to wash. It is for this reason that clay soils wash so readily.

Some facts about the porosity and the texture of soil. — Any soil that is well drained and loses its free water rapidly is a warm

soil, sometimes called an "early soil." Such soils get warm much quicker than do soils that hold water. For this reason a sandy soil may be ready for spring plantings a few weeks earlier than a clay soil. "It requires about twenty heat units to raise the temperature of one hundred pounds of dry soil one degree Fahrenheit.

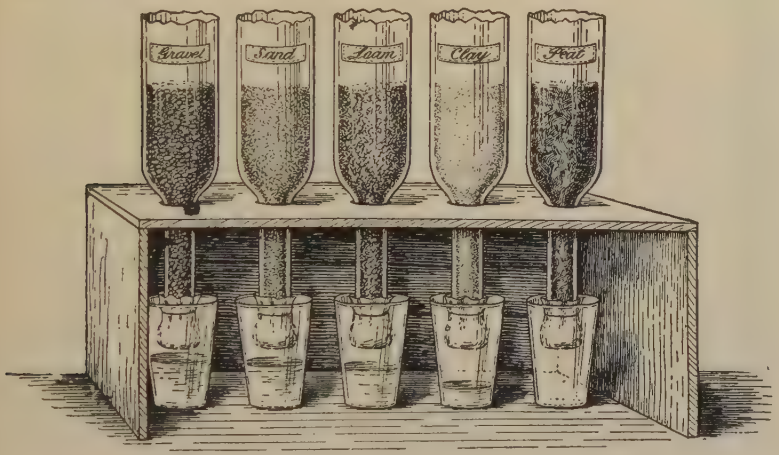


Fig. 12. — Cheap and simple apparatus to show percolation of water through five different types of soils

To raise the temperature of the same weight of water one degree Fahrenheit requires 100 heat units. But the effect of water is most striking when it evaporates. To evaporate 100 pounds of water requires 966.6 heat units."[1] Since clay soils will not permit percolation, most of the water must be taken off by evaporation. It is for this reason that a clay soil requires so much heat to warm it. All the heat is required to evaporate the surplus water. Since truck farmers want early crops, they prefer sandy soils because they get warm early.

[1] Warren, "Elements of Agriculture."

Coarse-texture soils permit the free circulation of air more readily than do fine-texture soils. This is one reason why sandy soils free themselves quickly of a surplus of soil water.

Fig. 13. — Percolation of water in silt and clay in 24 hours

The dotted sections represent unwetted soil.

Bacterial life is more active in an air-saturated soil than in a water-logged soil. Organic matter is transformed to available plant foods by bacterial life. A medium-dry soil aids in this work.

A soil of fine texture usually contains more available plant foods. This is true for two reasons: (1) The fine-texture soils have an origin with a better chemical basis. Sandy soils are of sandstone origin and contain little usable plant food. The clay soils are of limestone formation, and lime is needed in plant growth. (2) Fine soil particles expose more surface to the soil water, and thus chemical reactions take place more rapidly, and more plant foods are thereby produced and made available.

Adaptability of soils. — Soils of a sandy formation are adaptable to truck and vegetable gardening. Melons, onions, turnips, all root crops, and deep-rooted plants thrive best on sandy-loam soils. Grasses, which have a fibrous root system, do better in soils of a limestone formation. The corn, wheat, oat, and blue-grass regions have soils of a medium-fine texture, largely of limestone formation, mixed with some sand and a great deal of organic matter. Orchard soils should be of a loose, porous nature. They should be deep, and the subsoil should also be porous. Orchards will not thrive in a compact clay soil.

For general purposes, deep, black loam soils are the best. Black loam soils have about the following composition: humus, 3 to 5 per cent; silt, 40 to 60 per cent; fine sand, 5 to 10 per cent; clay, 10 to 25 per cent. Such soils are fairly fertile and are cultivated easily.

Summary. — The soil is our richest agricultural heritage. The texture of the soil refers to the size of the soil particles; clays have a fine texture, and sands a coarse texture. Water percolates through sandy soil rapidly and very slowly through clay soil. Sandy soils will hold less film, or capillary, water than clay soils. Sandy soils are therefore more adaptable to trucking, and heavier soils are suited to general farming.

LABORATORY EXERCISES AND HOME PROJECTS

1. Secure two kinds of sand — a fine and a coarse grade — and some clay. Wet each and examine it by rubbing it between finger and thumb. Describe each soil. Also hold the hand near the ear while rubbing. Describe the sound produced. Record your findings. Make a drawing in your notebook showing the comparative sizes of the particles examined.

2. Put a small quantity of coarse sand, fine sand, and clay in a tall bottle or test tube. Add water until the bottle is three-fourths full. Shake thoroughly, inverting the bottle occasionally while shaking. After the soil and water are well mixed, let the contents settle. Note the order in which the soils settle. Make a drawing and record your results.

3. Get two quart tin cans and make some small holes in the bottom of the cans, making the penetrations from the inside. Fill one can with a definite weight of sand, and the other one with an equal amount of clay. Pour water into each soil until it becomes thoroughly saturated. Keep pouring water in until some of the water passes through the soil and comes through the openings. Find the weight of water required to saturate each soil. The result will give the amount of water each of the two kinds of soils will hold. Write your findings.

4. In this experiment, if possible, use tubes (about an inch or two in diameter and three or four feet long), though long wine bottles with the bottoms broken out will do. Tie a piece of cloth over the neck of each bottle

and fill one bottle with well-pulverized clay and the other with sand. Pour water on each soil and take the time required for the water to percolate through each soil. Record your findings.

5. Using two of the longest tubes available, or wine bottles, as in Exercise 4, tie a cloth over the neck of each bottle and fill one bottle with the sand and the other one with clay. Now set the necks of the bottles in shallow water. See how long it will require the water by capillarity to rise to the top. Record as follows and write your conclusions:

HEIGHT OF WATER AT END OF SUCCESSIVE FOUR-MINUTE PERIODS

	FOUR MINUTES	EIGHT MINUTES	TWELVE MINUTES
Sand . . .			
Clay . . .			

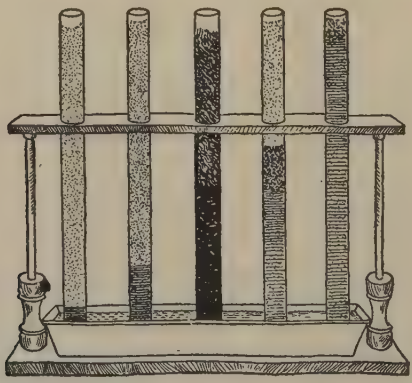


Fig. 14. — Pan and glass tubes, illustrating the apparatus used in showing the rise of water by capillarity

CHAPTER IV

STRUCTURE OF SOILS

Puddling of soils. — If clay or loam soils are driven over, tilled, or tramped when slightly wet, they pack readily; and when they dry out, they become hard. Heavy rains cause a hard crust to form upon the surface of many soils. The crust so formed is in poor physical condition. Walking over gardens when they are wet often does more harm to them than the removal of plant food during one season. Driving in fields even with a broad-tired wagon is very injurious to the soil. Fields or pastures should never be grazed when the soil is wet.

What causes the soil to form a crust after a rain, or what causes it to become packed if tramped when wet? Just as snow packs readily when at the proper temperature, so some soils pack readily when they contain an abundance of moisture. The soil particles slip one upon another, and in this slipping process they become compacted, or stuck very closely together. Soils that in a loose condition are six inches deep will occupy a depth of less than four inches after they are thus compacted. The compacting of soil is called *puddling*.

If the student will take two samples of dry clay and wet one thoroughly and leave the other sample dry, and then work each batch and set it away for several days, he will find that one batch

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: the same as in preceding chapter; some well-decomposed organic matter; and lime.

has become very hard. What has really happened? One soil has become compacted, or puddled, and the soil particles have slipped one upon the other, so that they are forced very closely together. The other has maintained a good structure.

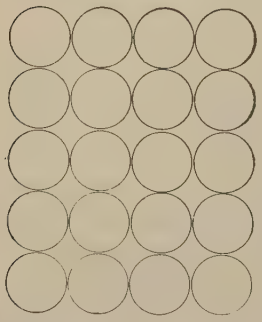


Fig. 15. — Soil particles in loose condition showing good structure

Meaning of soil structure. — The illustration (Fig. 15) shows how soil particles may rest one upon the other. As long as they remain in that position the soil is in good condition. Each soil particle is shown in contact with four other soil particles, and in reality each touches only six soil particles. These particles are about as far apart as they can get and still be together. It is a soil that is loose, friable, or workable, and in good tilth.

But suppose we wet the soil represented in Fig. 15 and then step on it with a slight push. What will happen? The soil particles will assume the position shown in Fig. 16.

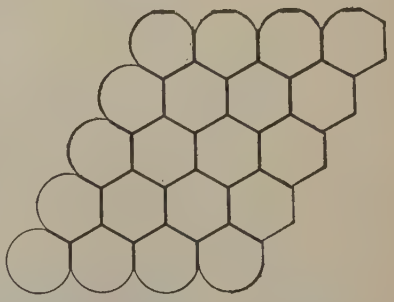


Fig. 16. — Puddled condition of the soil particles

Each particle now touches six other particles as shown here, while in reality it will be in contact with at least eight particles. What has happened? The arrangement of the soil particles has been changed. The soil has been compacted, and, after it has dried, it will form a very hard soil — one that will not respond to culture readily. Such a compacted soil will not permit free and ready air circulation and other processes due to chemical

and bacterial action, which are absolutely necessary for thrifty plant growth.

The best arrangement of soil particles is a granular one, for this is conducive to carrying on the processes necessary to plant growth. Such a soil is said to be flocculated, or in good tilth. It possesses a structure that makes the soil friable and actually sets free a maximum amount of plant foods. *Soil structure* then refers to the arrangement, or grouping, of the soil particles. Bacteria thrive in a soil of good structure if some organic matter is supplied, and plant growth is in a large measure commensurate with the activities of the soil bacteria. Chemical reactions are at their height in such a soil, if other conditions are favorable, and plant growth is again, in large measure, proportional to the chemical reactions in the soil.

Causes of bad structure in the soil. — Poor structure in the soil is caused mainly by three things: (1) improper tillage; (2) lack of organic matter; and (3) lack of drainage (Fig. 17).

1. If soil is worked when wet, it becomes so hard and compact that it requires a season or two to get it back into proper tilth. And as long as the soil is in poor tilth, it is hard to handle and does not yield good returns.

2. Much of the corn, wheat, and oat lands in the United States is in poor tilth because of lack of organic matter. Because the soil has been constantly tilled and the crops removed, many fields have been left void of organic matter. When the soil runs together after each rain and becomes compacted so that it is hard, it is a sign of the absence of organic matter.

3. Some of our lowlands, especially the black gumbo soils, are not in good structural condition because of the presence of too much water. When these soils are properly drained, they often make the very best soils because drainage aids in aëration, or air circulation, and this helps in the structural arrangement

of the soil particles. Uplands too are often in poor physical condition because of lack of sufficient drainage. We conclude, therefore, that improper tillage, lack of organic matter, and

Courtesy of International Harvester Co.

Fig. 17. — The result of lack of drainage

A wet-weather spring in the background prevents this field from being cultivated in early spring, causing the wet strip in the middle and the dry and cracked condition over a large section. A tile drain at the head of the spring would pay for its cost every year (Fig. 19).

improper drainage are often causes for poor structural condition of the soil.

Factors conducive to good structure and tilth. — While there may be other factors which are conducive to good soil structure, the principal ones are: (1) tillage; (2) addition of organic matter;

(3) use of winter cover crops; (4) use of lime; (5) the freezes of winter; and (6) the growing roots of plants.

1. Tillage has ever been a most powerful factor in putting the soil in good tilth. The use of the plow, the harrow, and the roller or drag is a powerful factor in promoting soil processes. Stirring the soil after a rain, and thereby breaking up the soil crust, conserves the moisture, admits the air into the soil, and helps to make plant foods available.

2. Organic matter, whether added to the soil in the form of barnyard manure, green cover crops, or plants and stubble, has an important effect upon soil structure. Organic matter incorporated into the soil prevents puddling of the soil to a considerable extent.

3. Winter cover crops protect the soil from beating rains and shield it from the direct rays of the sun. The sun burns out organic matter and hence affects soil structure. It is a well-founded belief that cover crops will help greatly in maintaining good soil structure and in maintaining or improving soil fertility.

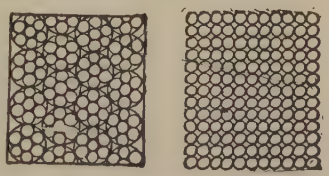


Fig. 18. — Limed and unlimed soil

At left, flocculation due to liming; at right, particles remain separate in unlimed soil.

4. Liming the soil not only sweetens it but flocculates the soil particles. In other words it helps to make the soil granular. Soil particles group themselves around other soil particles as shown in Fig. 18. A garden that packed with every rain was limed and manured. Its tilth was improved and its productiveness approximately doubled.

5. Winter freezes improve the physical condition of the soil as no other factor does. A soil that has been exposed to a cold winter has a crumbly structure and falls apart easily. Farmers

often say after a severe winter that there will be a good corn crop. And if no beating rains come in the spring, the statement has this basis: that the freezing winter has left the soil in good physical condition.

6. Growing roots and decaying roots aid in improving the physical condition of the soil. Deep-penetrating legume roots loosen the soil and upon decaying leave it looser and more porous. The decaying roots of grasses and other plants improve soil structure.

These six factors, tillage, addition of organic matter, use of winter cover crops, use of lime, freezes of winter, and growing roots, are important factors in influencing or improving soil structure.

Why plants grow well in a soil of good tilth. — No one would expect to grow a good garden or crop if he did not plow the soil and keep it in good physical condition. Why do plants thrive better if the soil is in good tilth? In the first place, plants do best in a loose soil because the roots can penetrate easily, without physical effort, every small space of the soil. The roots reach out in great bunches like double hands put together for plant food. These rootlets and root hairs entwine about the soil particles and voraciously devour all the plant foods the soil will readily give up.

In the second place, soils that are compact will not admit sufficient air. When the plant is growing rapidly, the chemical processes and bacterial action of the soil must be continued correspondingly, for otherwise not a sufficient amount of plant food is liberated. The organic matter in the soil does not give up its chemical ingredients unless there is sufficient air present. And since air can not well penetrate a compact soil, it is evident that we can not have good vigorous plant growth in such a soil. Hence plants will thrive in a loose soil because it admits air.

A third reason why plants do better in a soil of good tilth is that the soil moisture is kept in a more satisfactory condition than in a compact, puddled soil. A hard soil cracks open in dry weather and becomes water-logged in wet weather. A soil of good tilth holds its moisture remarkably well, even in extremely dry seasons, and permits the water to percolate through it in extremely wet conditions.

Summary. — Soil structure refers to the arrangement, or grouping, of the soil particles. When the structure of a soil is broken down, it is said to be in a puddled condition. When the soil is in such a condition, plants will not flourish because the processes essential to plant growth are lacking. On the other hand, when the soil is put in good structural condition by tillage, by addition of organic matter, by winter cover crops, by use of lime, by winter freezes, and by the growing roots of plants, then it is in a condition favorable to the processes essential to plant growth. The factors in improving soil conditions should be carefully studied and practiced, for they aid in permitting the air to circulate in the soil and thus induce the bacterial and chemical changes necessary to making available an abundance of plant foods.

The physical properties of the soil should be carefully guarded, protected, and improved, for thrift in plant growth depends as much upon the physical properties of the soil as upon its chemical properties.

LABORATORY EXERCISES AND HOME PROJECTS

1. Put about equal quantities of clay in each of two saucers. Add enough water to each to saturate it well. Stir one thoroughly. Do not stir the soil in the other saucer. Set both away and let them dry. After they are dry, try to crumble each between finger and thumb. Record your findings. What important principles pertaining to farm practices may be deduced from the experiment?

2. Mix together about equal quantities of well-decomposed organic matter and ordinary soil. Wet well and stir the mixture thoroughly. Wet and stir another batch of the same soil without the organic matter. Set the two soils away to dry. After they are dry, pulverize each soil with your hands. Record your findings as to the effect of the presence of organic matter upon soil structure.

3. Take two batches of clay, each weighing two hundred grams. Add to one batch 50 grams of lime. Mix well. Leave the other batch unlimed. Wet each soil thoroughly and work into a mud ball or brick. Set them away to dry. When dry, pulverize them with your hands. Record your findings. What effect does liming have upon the structure of the soil?

4. If test tubes are available, use them; if not, use tall bottles. Put an equal amount of clay and lime into one bottle, and into the other bottle put clay alone. Fill up each bottle with water. Mix thoroughly, then let the bottles stand until the water above the soil in each becomes clear. Record your results and make a drawing showing the results. Record the time required for the water in each bottle to become clear. How do you account for the difference?

5. Define structure, puddling, baking, and flocculation as applied to soils. Write the definitions, and append a statement with each definition.

CHAPTER V

PLANT FOODS

Physics and chemistry of the soil. — In the preceding chapters the physical properties of the soil were discussed. The formation of the soil, soil-forming agencies, and soil texture and structure are physical aspects of the soil. The importance of the physical properties of the soil can hardly be overemphasized, for the chemical, bacterial, and other processes of the soil depend very greatly upon its physical condition. Plants will grow poorly in a soil in which the structure is broken down. In the past we have not given sufficient attention to the *physics* of the soil, for it is one of the most essential factors in plant production.

We now turn to the *chemistry* of the soil, and the following chapters will deal largely with its chemical properties. Plant foods in the soil — how these may be lost and how they may be added — are topics for further treatment. The chemical composition of the soil, the sources of the plant foods, and their function form a study correlative to the study of the physical properties. The fertility of the soil is determined by its chemical and physical properties, and, let us not forget, the perpetuity of the race is directly dependent upon the fertility of the soil.

The cycle of life. — Plants take up plant foods from the soil, store them up temporarily, then die, decay, and disintegrate, and add their substance to the earth again. They gather plant foods from the soil and from the air — chemical elements and chemical compounds — and build them with the aid of the energy-giving sun into foods in the plants. These foods in the plants are similar to the plant foods in the soil; they contain the same chemical

elements and compounds and possess this difference only, that the proportions are different. How could plants be much different in chemical composition from the soil from which they come? The plant life that is consumed by animals is returned for the most part to the soil. Eighty per cent of the plant foods eaten by animals are returned to the soil in the manure. The animal, upon death, returns the other twenty per cent. The old statement — "that nothing is ever gained or lost" — holds quite true of Mother Earth. From soil to plant and occasionally from plant to animal, but always back to soil — this over and over again is the cycle of plant foods.

Foods required by plants. — Plants require those foods that they store up. Then the quickest way to see what their requirements are is to see what their chemical composition is. The chemical composition of 1000 pounds of corn plants, ready to be put into shock, is as follows:

CHEMICAL COMPOSITION OF THE CORN PLANT

Corn plant 1000 pounds	Water 793	Hydrogen 88.1		
		Oxygen 704.9		
	Dry matter 207	Organic matter 195	Protein 18	Nitrogen 2.9
				Carbon 90.5
			Fat 5	Oxygen 88.9
				Hydrogen 12.7
			Fiber 50	
			Carbohydrates 122	
		Mineral matter 12	Chlorine 0.4	
			Potash 4.0	
			Phosphoric acid 1.2	
			Lime 1.6	
			Magnesia 1.4	
			Iron oxide 0.3	
			Sulphuric acid 0.3	
			Soda 0.4	
			Silica 2.4	

The corn plant is taken here as a representative plant in chemical composition. From the composition above given it may be

seen that hydrogen, oxygen, carbon, and nitrogen, with the exception of 12 pounds of mineral matter, or ash, compose the entire 1000 pounds of corn plant. These four elements, in the form of water, protein, fat, fiber, and carbohydrates, constitute 98.8 per cent of the entire corn plant. All the ash elements in the corn plant except chlorine are in combination with the element oxygen. Other plants, although varying from corn in the amounts of different chemical compounds, are very much like the corn plant in composition.

What plant foods we find in the soil. — The *ash elements* — phosphorus, calcium, iron, sulphur, magnesium, sodium, and silicon — all in combination with oxygen, are found in the soil. Silicon in combination with oxygen forms sand. Potassium combined with nitrogen and oxygen forms potassium nitrate. Iron is found in abundance in soils, where it is combined with oxygen. The reddish-brown color of some soils is due to the iron rust in them. Magnesium plus sulphur makes magnesium sulphate, or Epsom salts. These are the essential mineral, or ash, elements in the soil. The three ash elements most frequently lacking in the soil are calcium, or lime, phosphorus, and potash. All the rest are usually present in sufficient quantities.

The elements nitrogen, hydrogen, oxygen, and carbon constituting 98.8 per cent of the corn plant come from the soil and the air. Hydrogen and oxygen combined make water, which constitutes from 75 to 90 per cent of green plants. Water comprises from 20 to 25 per cent of the weight of average loam soil under good field conditions. Carbon in the form of carbon dioxide is taken into the leaves of plants, and in the chlorophyll of the leaves it combines with hydrogen and oxygen. Nitrogen, making up four fifths of the air, is used by the legumes directly, through the help of soil bacteria in the form of soil air. Nitrogen in decaying organic matter changes to nitrates which can be absorbed by any plant.

The foundation rock from which the soil was made with the organic matter added to the soil is the source of many of the plant foods.

Function of the different plant foods. — Water is one of the chief foods of plants. Its functions are: (1) to actually help build up the plant; (2) to carry other plant foods in solution into the plant; and (3) to equalize the temperature of the plant by transpiration. Carbon, hydrogen, and oxygen form the *carbohydrates*, which comprise the starches and the sugars. *Fats* are likewise composed of these three elements. Carbon, hydrogen, oxygen, and nitrogen make up the *protein* substances in the plant body. Luxuriant green plant growth is an indication of an abundance of available nitrogen. Often pear and apple trees grow so luxuriantly that they refuse to bear. One reason for this in many cases is an oversupply of nitrogen and a lack of other elements. Nitrogen must be supplied if protein substances are to be grown. The nitrogenous ingredient in plant growth is the most valuable and is often scarce in the soil. Nitrogenous fertilizers are high in cost. The composition of the corn plant (p. 40) indicates in a quantitative way the function of the elements that make up the organic part of the corn plant.

The ash elements form a small part of the plant. The ash ingredients in a few feeding stuffs are shown in the following table:

ASH INGREDIENTS PER 1000 POUNDS

	Total Ash in 1000 Pounds	Pounds of Each								
		Potash	Soda	Lime	Magnesia	Iron Oxide	Sulphuric Acid	Phosphoric Acid	Silica	Chlorine
Wheat	25.15	5.3	1.6	0.6	2.2	0.23	5.4	8.6	0.4	0.82
Wheat bran	64.54	16.2	2.4	0.9	7.3	0.34	6.7	29.5	0.3	0.90
Alfalfa hay	81.02	22.3	5.6	19.5	5.9	1.68	7.8	5.4	8.1	4.74
Skim milk	8.21	1.7	0.6	1.8	0.2	0.0	0.8	2.2	0.0	0.91

Potash helps to build stems, especially giving stiffness; lime aids in forming leaves; phosphoric acid assists in forming the kernels of plants and hastens maturity. The other ash elements also help plant growth. The complete function of the ash elements is not now known.

Amount of plant foods in soils. — The following table gives a fair notion as to the composition of a few soils, giving the nitrogen, phosphoric acid, and potash content per acre.

AMOUNT OF PLANT FOOD PER ACRE IN THE SURFACE FOOT

	NITROGEN (Pounds)	PHOSPHORIC ACID (Pounds)	POTASH (Pounds)
Peat	11,865	550	1,697
Sand	1,675	620	39,750
Clay	3,250	5,600	12,600
Black clay loam	12,360	5,720	67,730

A close study of the table will reveal what fertilizers, if any, are to be applied to different kinds of soils. A peat soil is rich in nitrogen and poverty-stricken in phosphoric acid and potash. It is evident that it does not need a nitrogenous fertilizer. A sandy soil may need nitrogen and phosphoric acid.

Amount of plant foods removed by plants. — Corn, wheat, and oats remove the following amounts of food elements.

AMOUNT OF PLANT FOOD REMOVED BY PLANTS

	NITROGEN (Pounds)	PHOSPHORIC ACID (Pounds)	POTASH (Pounds)
Corn, 30 bushels	43	18	36
Wheat, 30 bushels	48	21	28
Oats, 45 bushels	55	19	46

How many years would it require corn to remove the nitrogen, phosphoric acid, and potash from a clay field, which has the composition indicated in the preceding table, corn yielding thirty bushels per acre yearly? It would require 76 years to remove the nitrogen; 311 years to remove the phosphoric acid; and 350 years to remove the potash. This clearly indicates that the plant foods of the soil can not be quickly removed. And we should bear in mind that, if the same land were tilled in the same crop year after year, it would soon refuse to release as much plant food as it did the preceding year or decade. This is a fortunate thing, for it protects the soil from the unscrupulous soil robber.

Three forms of plant foods in the soil. — Plant foods exist in the soil in three forms: (1) plant foods that are immediately available; (2) those that are not immediately available; (3) those that are firmly secured in the soil.

1. The plant foods that are immediately available to plants constitute a small part of the total plant food in the soil. The plant foods are held in solution by the soil water, and if plants are present they are used; if not, they may leach away. Good soil texture and structure and plenty of organic matter prevent to a large extent the leaching away of plant foods. Cover crops help hold available plant foods — for in this case the available plant foods get into the round, or cycle (p. 39) — and the plants hold secure for a short time the foods that the soil yields them.

No one could guess or even determine what quantity of plant foods are available and made available in one season. This, in fact, depends upon several conditions (discussed in the next paragraph), but that probably less than one-hundredth part is available in one season is a safe, conservative estimate. This is a fortunate thing indeed, for, if all the plant foods became available in one season, exhaustion of the soil would soon occur.

2. The plant foods not immediately available to plants and

found in the surface soil make up another fractional part of the total plant foods in the soil. Let us think of this form of plant food in this way — there are some plant foods available; others are becoming available in 30, 60, 90, 180, and 360 days. The rock particles in the soil in the presence of humus yield up slowly their plant foods. Year in and year out chemical and bacterial processes are going on in the soil, ever changing and drawing upon Mother Earth, trying to get plant foods. The plant foods that are not immediately available do not help or contribute plant foods to the growing plant. These plant foods will yield themselves to service later.

3. Those plant foods that are firmly secured in the soil constitute probably ninety-nine per cent of all the plant foods in the soil. The bowlders and rocks hidden beneath the surface of the soil — in some places near the surface, in others farther away — hold within themselves plant foods that will feed plants hundreds and thousands of years from now. The surface soil was made from these original rocks and it took ages to do it. These parent rocks deep down in the soil are the permanent storehouses and securities of plant foods forever. But even these permanent storehouses will finally, as the result of heat and cold, plants and animals, sunshine and rain, yield themselves to plant growth, if they are needed.

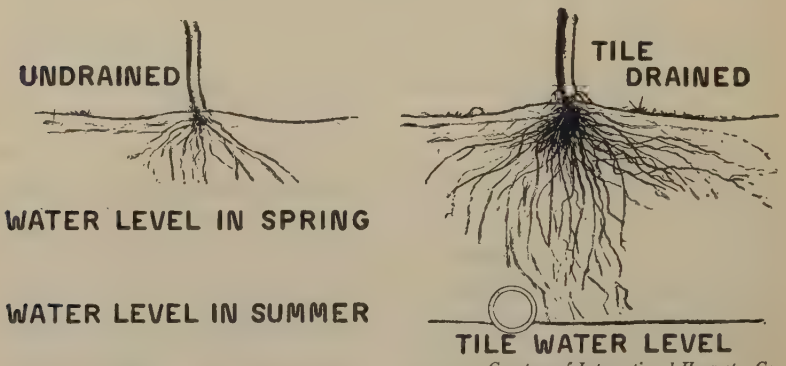
Although chemical analysis is very valuable in determining the total amount of plant foods in the soil, it does not show the amount of plant foods available for plant growth. Hence chemical analysis is rather of indirect than of direct value.

How to make plant foods available. — Some of the factors that help to make plant foods available or to set them free are to be discussed:

1. Tillage, keeping the soil in good tilth, is the greatest factor in setting foods free so that plants can use them. Tillage too

helps in giving the roots of plants more surface area upon which to feed, thus enabling them to utilize the available plant food. The structure of the soil must be in proper condition if a maximum amount of plant food is to become available.

2. The addition of organic matter does more than to add a great deal of plant food. It aids in drawing plant foods from the rock particles.



Courtesy of International Harvester Co.

Fig. 19. — Root growth in undrained and drained soil

In the early spring the roots had to seek food and growth above the water level; when the ground dried out in summer, they could not break through the hard soil; besides, they were already established in the top soil. Hot, dry days soon burn up the shallow-rooted plants.

3. Proper drainage carries out the excess water. Plant foods are not made available rapidly where there is an excess of water (Fig. 19), for it keeps out the air, and air must be present if chemical and bacterial changes are to go on to set plant foods free. From twenty to twenty-five per cent moisture is the amount best suited to plant growth.

Balancing the ration for plants. — Plants, like animals, must have a balanced ration if they are to yield well. Fig. 20 shows to some extent the significance of an unbalanced ration in plant growth.

The illustration shows the importance of providing nitrogen if plants are to thrive. It is just as true that all other essential elements must be provided also.

The chemical composition of plants given in this chapter indicates the needs of plants, but all the ingredients needed must be supplied in much greater abundance than the composition of the

Courtesy of College of Agriculture, University of Illinois

Fig. 20. — Effect of inoculation on cowpeas

At left, a complete fertilizer was used without inoculation; at right, germs supplied the nitrogen; in middle, plants were not inoculated and received no nitrogen.

plants indicates. That this is true is shown by the composition of a few soils given on p. 43.

Balancing plant foods is an important matter. One element can not take the place of another element. If there is sufficient nitrogen in a soil to produce forty-five bushels of wheat to an acre, potash to produce fifty bushels, and phosphoric acid to produce twenty bushels per acre, the maximum yield can not

exceed twenty bushels per acre, because the scarcity of phosphoric acid in the soil prohibits the greater yield. It is an unbalanced ration in the supply of plant foods. Phosphoric acid is the limiting factor. "No chain is stronger than its weakest link." The weakest link in the above chain is phosphoric acid.

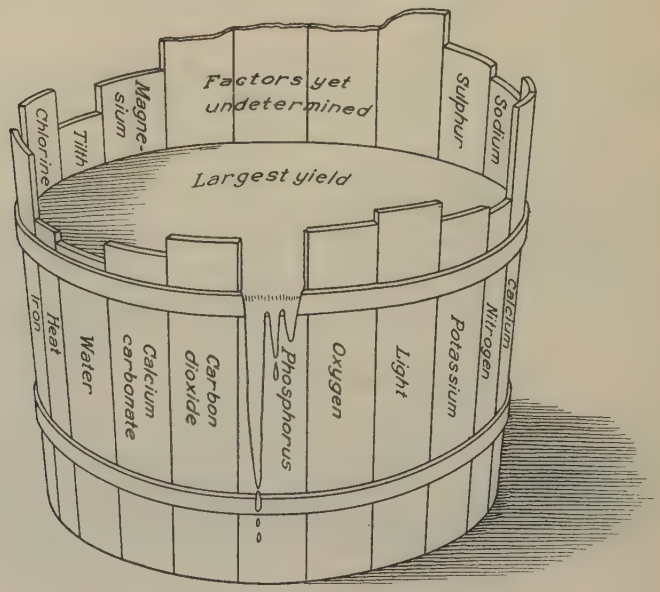


Fig. 21. — Just as the height of the lowest stave determines the amount of water the barrel can hold, so the yield of a crop on a field is determined by that element or condition which is least satisfactory

The balancing of plant foods will be further discussed in later chapters.

Summary. — The plant foods in the soil are all important in the perpetuation of a successful agriculture and of a successful race. Plants are the medium through which plant foods are taken from the soil and returned to it. Plants require hydrogen,

oxygen, nitrogen, carbon, potash, calcium, phosphoric acid, magnesium, iron, and sulphur in their growth. The three non-essential plant foods, often found in plants, however, are sodium, silicon, and chlorine. The essential ones do their part in building up plant tissue and each has a definite rôle to play in this building process. One element can not take the place of another element in plant growth. The amount of plant foods in the soil in an available, not immediately available, and a tightly secured form is fortunately fairly large. That the earth yields up its storehouse of plant food slowly is a fortunate thing. Man may by tillage, addition of organic matter, and drainage help make plant foods available. Plants must be supplied a well-balanced ration if they are to produce at their best.

LABORATORY EXERCISES AND HOME PROJECTS

1. Nearly fill two one-gallon buckets or jars with subsoil. To one of these add about a quart of well-decomposed manure or organic matter. Plant about six kernels of corn or some wheat in each. Maintain good conditions for growth. Examine and record findings for about ten weeks of growth.

2. Have pupils bring as many kinds of rock as are found in the locality and examine specimens as to color and hardness. If rock can not be broken with the hands, use a hammer. Study the solubility of the rocks brought by putting parts of the rock in water.

3. Describe in a well-written report the soil and the subsoil of a fertile and a non-fertile field in your neighborhood. Describe texture, structure, color, depth, etc. Mention the kind of rock or rocks from which the soil was formed.

CHAPTER VI

SOIL WATER

Importance of water in crop production. — Water is more often the limiting factor in plant growth than any other single factor and for that reason should receive special emphasis. From seventy-five to ninety per cent of the green weight of the staple crops is water. And much more is needed in proportion to produce the dry matter which is found in the dry plant, for from 200 to 700 pounds of water transpire from crops for every pound of dry matter produced.

These figures vary a great deal, for arid, warm, clay soils and windy conditions require more moisture than do the converse conditions. Plants need water for various reasons:

1. It makes up a large part of the composition of the plant and is an actual plant food.

2. It serves as a carrier of plant food. Plant foods are taken into the plant through water solutions. These plant foods are carried in such small quantities, especially the mineral ingredients, that it is necessary for enormous quantities of water to pass through plants in order that they may be properly nourished.

3. Water helps to maintain the proper temperature of plants. Water, in the transpiration process, cools the leaves to a considerable extent. Young shoots of plants would be burned up were it not for the cooling effect of the water that passes through them and transpires from the leaves.

Water in proper amounts and coming at the right seasons practically controls the yields. Twenty inches of rainfall when prop-

erly distributed is sufficient to produce the best corn yields, but when improperly distributed an absolute failure of the crop may result. Sometimes an additional rain or two would double the crop yield. Hunt and Burkett, in "Soils and Crops," say: "A piece of land was once planted in corn. The yield was 30 bushels

Courtesy of U. S. Department of Agriculture

Fig. 22. — Annual rainfall in the United States

per acre. The next year it was planted with the same kind of corn and otherwise treated as in the previous year. The yield was 90 bushels. During the first season the rainfall for the five growing months was thirteen inches; the second season it was twenty-two inches for a like period. The extra nine inches of rainfall was the principal factor in producing the additional 60 bushels of corn."

Amount of water in the soil. — There are several ways of finding the per cent of moisture in the soil. United States Bulletin

No. 9 gives a simple method: "The loss in weight upon drying soil at a temperature of 110° C. is the amount of moisture." That is, if one hundred grams of soil weighed eighty grams after drying, the per cent of moisture would be $\frac{20}{80}$, or 25 per cent.

The amount of water a soil holds depends upon the texture and structure of the soil and the amount of organic matter it contains. The volume and per cent of water held by different soils is shown in the following table:

WATER-HOLDING CAPACITY OF SAND, CLAY, AND MUCK

KIND OF SOIL	POUNDS OF SOIL PER CUBIC FOOT	POUNDS OF WATER PER CUBIC FOOT	PER CENT OF WATER IN SOIL AT SATURATION	
			(Wet basis)	(Dry basis)
Coarse sand . . .	81	32.0	28.3	39.5
Clay	68	37.0	35.2	54.4
Muck soil . . .	15	50.0	77.0	333.3

This table shows that a muck soil (the same is true of a peat soil) will hold much more water than a clay soil, and that a clay soil has greater water capacity than sand. However, it should be noted that a sandy soil will give up its water content more quickly than a clay or muck soil. Crops will begin to wilt in a coarse sand soil when the moisture gets below 3 to 4 per cent; in a clay soil when the moisture gets below 17 per cent; and in a muck soil when soil moisture gets below 80 per cent. The average soil, containing 15 to 30 per cent water, provides, as far as soil water is concerned, the best conditions for plant growth. The above per cents are figured on the dry basis of figuring moisture content.

Three forms of water in the soil. — Water exists in the soil in three forms: (1) gravitational water; (2) capillary, or film, water; (3) hygroscopic water.

1. *Gravitational water* moves in the soil by force of gravity. Under such a condition all the pore spaces are saturated with water, and the water is gradually sinking under the influence of its own weight. It was shown in the preceding paragraph how much water soils would hold when saturated. Few plants can use gravitational water to advantage. When the soil is saturated, the air is pressed out of the soil, and the processes essential to plant growth are greatly curtailed. It is for this reason that plants get yellow.

Fig. 23. — Movement of capillary water

Three tubes filled with soil were placed with their lower ends submerged in water for two hours. The black indicates how far the water rose in each tube.

2. *Capillary, or film, water* is held on the soil particles by capillarity. If the finger is inserted into water and then removed, it will have a film of water about it. The capillary water is held similarly by the particles of the soil. The amount of capillary water a soil will hold depends upon its texture, structure, and organic content. Clay soils will hold much more capillary water than sandy soils, and organic matter will hold more still. Buckingham found that fine sand, sandy loam, clay, and peat hold 10, 15, 20, and 190 per cent capillary moisture respectively.

The movement of capillary water may be in any direction. It

may be upward, for plowed soils that appear dry during the daytime are black the following morning because moisture has come to the top of the soil.

3. *Hygroscopic water* is water that condenses about the driest dust particles. The amount of hygroscopic water in dry road dust may range from 1 to 4 per cent. Sandy soils do not hold as much hygroscopic water as do clays or black loams. Hygroscopic water being unavailable to plants, therefore, does not need further discussion.

How to increase the water-holding capacity of soils. — Cultivation and putting the soil in the best of physical condition are important factors in increasing its water-holding capacity. Time of plowing is a powerful factor in increasing the water supply of a soil. At the Kansas Station the time of plowing had the following effect upon soil moisture:

EARLY PLOWING HELPS IN CATCHING AND HOLDING WATER

	GAIN IN MOISTURE JUNE 1 TO SEPTEMBER 21			LOSS IN MOISTURE APRIL 1 TO MAY 31		
	Moisture Content June 1	Moisture Content Sept. 21	Gain	Moisture Content April 1	Moisture Content May 31	Loss
Late-fall plowed	14.9%	18.3%	3.4%	16.9%	15.5%	1.4%
Early-fall plowed	13.7%	19.6%	5.9%	17.0%	14.6%	2.4%
Fallowed . . .	14.5%	21.5%	7.0%	20.4%	16.3%	4.1%

The table shows that fallowed ground gained more moisture from June 1 to September 21; also gave up more moisture from April 1 to May 31; and still contained more moisture than did the late-fall plowed soil. Fall-plowed soil will catch and hold more moisture than spring-plowed soil.

Since organic matter has about seven times the water-holding capacity that clay has, it is quite evident that organic matter

added to clay soils will help to increase the water-holding capacity. Manure will improve the texture and structure of the soil so that the rainfall will be taken into such a soil much more readily than where manure is not applied.

Courtesy of International Harvester Co.

Fig. 24. — Swamp land

There are millions of acres of swamps — areas of great fertility — which can be made productive.

Sandy soils are also improved in their water-holding capacity by compacting them. For this reason rolling or dragging has a good effect upon sandy soils.

Plants which shade the earth help the soil to hold its water content. When the soil is well protected from the sun and wind, its moisture is pretty well guarded. Bare spots in the pasture or lawn permit the escape of soil moisture. As far as possible

no soil water should be permitted to escape from the soil, agriculturally speaking, save through the leaves of useful plants.

Regulating the moisture supply in the soil. — This topic comprises three other topics: drainage, irrigation, and mulching. Only a brief discussion of each can be attempted here.

Drainage. — There are nearly 80,000,000 acres of swamp lands in the United States which may be reclaimed by drainage. These

Courtesy of International Harvester Co.

Fig. 25. — Effect of drainage

This fine, broad-leaved corn is growing where two years before was an unhealthful and unsightly marsh (at right).

lands will be drained gradually as they are needed. Many clay uplands, as well as swamp lands, need draining.

What benefits may be expected from drainage of swampy, undrained soils? Larger crop yields may be expected, and unproductive land may be made productive, as the illustration in Fig. 25 indicates.

Why an increase in yield from drained soils?

1. Drainage takes out the surplus water. This permits the soil to become warm and thereby lengthens the growing season anywhere from ten to forty days.

2. Drained fields suffer less from drought because the roots of plants penetrate the soil more deeply. This insures the plants more feeding surface and as a result more moisture.

Courtesy of International Harvester Co.

Fig. 26. — A pot-hole lake on a $200-an-acre farm which was made to produce fine corn by drainage (Fig. 27).

Besides being a waste of land, this hole is the hatching place of hordes of mosquitoes.

3. Drainage opens up the soil and permits the air to get in. This helps in making more plant foods available, for the oxidizing action of the air aids the chemical and bacterial processes in the soil.

4. Drained fields can be tilled and handled much more easily than undrained fields. This is a powerful factor in making plant foods available and in securing maximum crop yields.

5. Drainage prevents washing and hence conserves the fertility of the soil.

6. Drainage makes waste lands available for agriculture, thus helping to swell crop production (Figs. 26, 27).

Courtesy of International Harvester Co.

Fig. 27. — The result of drainage

Corn nine feet high is growing on the site of the lake in Fig. 26. A marvelous change from early spring to fall of the same year.

The drainage of large areas is distinctly a national and state problem, for it requires the coöperative effort of local, state, and Federal governments. Professor Shaler estimates that there are about 3,000,000 acres of land that may be reclaimed along the Atlantic seaboard of the United States. These lands when

reclaimed by proper drainage are the most fertile and valuable lands we have.

Irrigation. — The rainfall map (Fig. 22) shows the average annual precipitation in the different parts of the United States.

Nearly two fifths of the United States is too dry to produce crops well without irrigation. The total land now irrigated is about twenty million acres.

The water used in irrigation comes from streams, lakes, ponds, and storage reservoirs. The water is carried by either pipes or trenches, and when it reaches the soil that is to be irrigated it is carried to its final destination by small ditches. There are four methods of applying the water; namely, (1) flooding; (2) furrow distribution; (3) overhead sprays; and (4) subirrigation. Each method has its advantages and its disadvantages with different crops and different conditions.

A soil that is hard, packed, or cracked loses soil water rapidly, for the sun, wind, and air take it up as fast as the water is exposed. Fig. 17 shows a condition which permits the escape of the maximum amount of soil water.

Hard soils begin to crack upon the approach of dry weather. Nothing can happen that will more quickly reduce the plants, for the plant is rapidly being robbed of the moisture that rightfully belongs to it. When the moisture is once evaporated, it can never be regained. The question that confronts every soil husbandman is, How may I conserve the moisture that is in the soil of my farm?

The answer is the *soil mulch.* This is a blanket of soil two to three inches deep made by cultivation. The mulch is not in close granular contact with the soil beneath, although the mulch should be granular. It breaks the capillary movement of the soil water. Cultivating the soil breaks the direct contact of capillary water with the forces causing evaporation.

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Fig. 28 shows the difference between a compact soil, conducive to evaporation, and a mulched soil, which prevents the escape of soil water.

Every soil husbandman of garden, orchard, or field knows the value of a soil, straw, sawdust, or leaf mulch. He also knows that stirring the soil during the hottest weather by plowing the

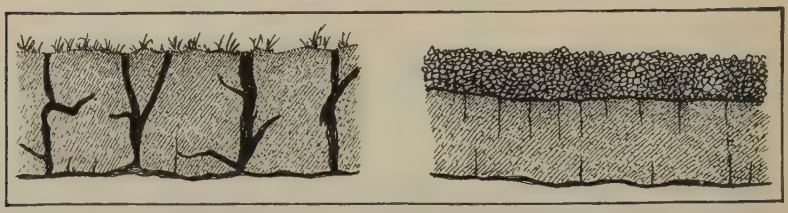


Fig. 28. — Effect of a soil mulch

At left, moisture escapes through cracks; the sun and wind are rapidly taking away the soil moisture; at right, a soil mulch prevents cracking and helps to hold the soil moisture. It also breaks to a large extent the capillary rise of water in the soil.

corn conserves the moisture and increases the yield. To indicate the water saved by the soil mulch, the following figures are submitted:[1]

MOISTURE CONTENT OF MULCHED AND UNMULCHED EASTERN MONTANA SOILS

(Average of Three Years, October 6)

	MULCHED (Per cent)	UNMULCHED (Per cent)
First foot	16.8	10.8
Second foot	16.4	9.4
Third foot	13.2	9.5
Fourth foot	10.1	8.9
Fifth foot	9.6	8.5
Averages	13.2	9.4

[1] Lyon, Fippen, and Buckman, "Soils, Their Properties and Management."

The authors state, "If the wilting point was six per cent, then the mulched soil contains more than twice as much available moisture as the unmulched." The table is worthy of the most careful consideration in the study of the management of the soil.

A soil mulch from two to three inches deep has been found most effective. Stirring the soil after each rain in order to break up the crust formed by the rain is a good practice in conserving soil moisture. A fairly coarse granular soil mulch is most effective. A fine dust is undesirable, because the soil particles remain too close together in a finely pulverized soil mulch. The term "dust mulch" should disappear, and the word "soil mulch" be used instead.

Level cultivation is also an important factor in saving soil moisture. Ridging corn and potatoes, known as *laying by*, should be abandoned, because ridging the soil exposes more soil to the sun and air and therefore causes an excess evaporation.

Summary. — Soil water is important because it is the most frequent limiting factor of plant growth. Plants require from 200 to 700 units of water for transpiration for each unit of dry matter produced. The function of water is to build plant tissue, carry plant foods, and maintain the proper temperature of the plant.

The average farm soil under good field conditions contains from fifteen to thirty per cent of moisture. The three forms of soil water are gravitational, capillary, and hygroscopic. Capillary water can be used by field plants. Tillage, addition of organic matter, and the shade of plants help to conserve the moisture of the soils.

Soil moisture may be regulated by proper drainage, irrigation, mulching, and level cultivation. If we want a big crop yield, we must carefully husband the water in the soil.

LABORATORY EXERCISES AND HOME PROJECTS

1. Secure some soil from a near-by field. Weigh out, say, 250 grams; put it in a vessel and heat it over a stove until all the moisture is driven off. Weigh the dry soil. Find the per cent of moisture the soil contained.

2. Take 200 grams of the driest road dust obtainable, and by the method described in Exercise 1 find the per cent of hygroscopic water that it contains.

3. As an experiment to see a representation of the way a soil mulch conserves soil moisture, take a cube of ordinary loaf sugar (Fig. 29), the large size, about one inch square. On top of it heap powdered sugar, about a quarter of an inch thick. The cube of sugar represents the soil, and the powdered sugar the soil mulch which we get by harrowing, disking, or cultivating the ground. Then take a common drinking glass with a concave bottom, dilute in water a few drops of writing ink, or use other dark liquid (coffee will do), and place the cube of sugar in the fluid. Note how quickly the dark inky solution rises toward the top of the cube. The cube five seconds after it is placed in the solution will be colored halfway up. In ten seconds the color reaches the top, but there it stops. The powdered sugar "mulch" does not take it up as the solid lump of sugar did. If you let it stand, you will find that it takes an hour or longer for the dark liquid to soak through the powdered sugar.

The whole secret of conservation of moisture in the soil is clearly demonstrated by this simple test. If we disk and harrow the soil so that it has a fine mulch covering, this powdered soil will act like the powdered sugar.

4. Fill two quart tin cans with an equal amount of soil. Weigh each. Put one and one half inches of dust over the soil in one of the cans. Set both soils in the same place and weigh them on alternate days for three or four weeks. Record weights in the following manner:

Date	Mulched Soil	Unmulched Soil
Initial weight		
Weights of soils on intervening days.		
Final weight		
Total loss		
Percentage loss		

Courtesy of International Harvester Co.

Fig. 29

What are your findings? What conclusions can you draw from the experiment?

5. Fill a one-gallon bucket or jar with coarse sand and one with soil from a garden. Plant corn or wheat in each one. Maintain conditions so that the plants will grow. When plants have several leaves, stop watering them and note the number of days that elapse before the plants begin to wilt. As soon as the plants are well wilted, find the per cent of moisture in each soil, using about 200 grams of soil to make the test. Compare the per cent of moisture still remaining in each soil. Write your findings.

CHAPTER VII

FACTORS DECREASING SOIL FERTILITY

Factors affecting the fertility of the soil. — Some of the factors causing a decrease of soil fertility are: (1) soil erosion; (2) constant cropping; (3) loss of humus; (4) breaking down of the physical condition of the soil; (5) loss of nitrogen; (6) lack of conditions that foster bacterial growth.

1. *Soil erosion.* — Soil erosion causes the greatest loss of soil fertility. No other single factor lays such a heavy tax upon the fertility of our soils. The United States Yearbook of Agriculture of 1916 estimates the annual loss due to erosion at approximately $100,000,000. This enormous tax is a constant drain upon our resources. It never brings any returns and leaves the soil permanently depleted. Soil erosion has led to the abandonment of farms in various parts of the United States (Fig. 6).

The United States Yearbook of Agriculture, 1916, says: "Already some four million acres of farm land have been ruined by erosion and nearly twice as much more has been seriously damaged. In other words erosion has rendered completely nonproductive an area capable of forming nearly one hundred thousand farms, and of sustaining a population approximately equal to that of Arizona and New Mexico combined. Every year there is an unnecessary wash from erosion of more than four hundred million tons of soil material. Even a nation as rich in its resources as the United States can not afford a loss of this magnitude."

A story is told of a man who built his house upon the sand and the floods came and washed it away. Some of our farming may be likened unto the picture, for the washing away of the soil is certainly undermining our soil fertility and gradually diminishing one of our largest resources.

Soil erosion is due to the following conditions: slope; lack of vegetation; character of rainfall; and physical condition of the soil.

Slopes with a fall of more than fifteen degrees should not be cleared. However, some soils on slopes of less than fifteen degrees will wash easily, and even almost level fields may erode a great deal.

A lack of vegetation often permits erosion. Gullies form where the stock have worn away the vegetation and made a path. The fine-root systems of grass are very effective in holding the soil together. Slowly falling rains seldom wash the soil, but a heavy rain is often rightly spoken of as a gully washer.

Soils with fine texture and poor structure erode readily. Coarse sandy soils containing a lot of organic matter will not erode so readily. But the soil that has been tilled continuously and has lost most of the organic matter must be managed carefully, or there will be none to manage in a season or two.

There are several means available to prevent erosion:

(1) Keep gradually sloping land in grass, and protect open ditches with sod and hillsides with forests.

(2) Banks of streams should be protected from the flowing water by a fringe of trees.

(3) Open ditches having gentle slopes along the hillsides will prevent erosion. Plowing and cultivating should be along the side of the slope rather than up and down the slope.

(4) Increasing the water-holding capacity by putting the soil in the best physical condition and by the addition of manure will

assist greatly in preventing erosion. A soil in good physical condition does not wash easily.

(5) Terracing the soil aids in preventing washing. This is a common practice in Italy, France, Germany, and China and is being used to some extent in the United States (Fig. 2).

2. *Removing plant foods from soils decreases soil fertility.* — Constant cropping of soils and removing the crops reduces the fertility of the soil. Grain and hay crops remove fertility, as indicated in the following table:

The ingredients nitrogen, phosphoric acid, and potash are figured at 20, 7, and 7 cents per pound respectively.

FERTILIZING CONSTITUENTS PER TON OF PLANTS AND ANIMALS

	Fertilizing Constituents in One Ton			Fertility Value per Ton	Manurial Value per Ton
	Nitrogen (Pounds)	Phosphoric Acid (Pounds)	Potash (Pounds)		
Dent corn (grain)	32.4	13.8	8.0	$8.00	$5.43
Wheat	39.6	17.2	10.6	9.87	6.70
Oats	39.6	16.2	11.2	9.84	6.68
Timothy hay	19.8	6.2	27.2	6.30	4.45
Red clover hay	41.0	7.8	32.6	11.03	7.59
Oat straw	11.6	4.2	30.0	4.71	3.42
Corn silage	6.8	3.2	8.8	2.20	1.56
Cottonseed meal, choice	141.2	53.4	36.2	34.51	23.37
Fat pig	35.4	13.0	2.8	8.19	
Fat ox	46.6	31.0	3.6	11.74	
Milk	11.6	3.8	3.4	2.82	1.91
Butter	2.4	0.8	0.8	0.59	

That continuous cropping reduces soil fertility is shown in the following table.[1] The table also shows that rotation helps in protecting the soil to some extent.

[1] Ohio Station Bulletin No. 282.

ROTATION *versus* CONTINUOUS CRPOPING IN CROP YIELDS

	TREATMENT	AVERAGE YIELD PER ACRE				AVERAGE YIELD FOR 20 YEARS (BUSHELS)
		1st 5-yr. Period (Bushels)	2d 5-yr. Period (Bushels)	3d 5-yr. Period (Bushels)	4th 5-yr. Period (Bushels)	
Continuously in corn	None	26.26	16.76	10.43	8.44	15.5
Rotation, corn, wheat, clover	None	31.89	30.82	31.04	20.31	28.5

This table, like many others from the Experiment Stations, shows that continuous cropping reduces the fertility of the soil.

Courtesy of International Harvester Co.

Fig. 30. — Effect of rotation on corn yields

At left, 81 bushels per acre, 3-year rotation for 32 years; soil treatment applied last seven years only; at right, 36 bushels per acre; no soil treatment, corn grown continuously for 32 years.

Shipping animals from the farm and returning nothing also removes soil fertility. The amount of fertility thus removed is shown in the table on p. 67.

3. *Loss of humus decreases soil fertility.* — It has been said that humus is the life of the soil. And since humus comes from organic matter, it is evident, if the organic matter in the form of plants is continuously removed from the soil and none returned, that the soil will soon be very low in humus. This is one way in which humus is removed.

Soils unduly exposed to the hot, drying sun will lose their humus rapidly. A growing crop shading the ground, a cover crop, or a soil mulch will protect the humus content. The air oxidizes the organic matter and takes out its fertilizing ingredients.

The specific gravity of humus is 1.2 to 1.7; that of clay, 2.8; and of sand, 2.6. Humus is only about one half as heavy as soil, and the particles of humus are also very small. It is therefore evident that humus will be carried off by flowing water before the soil will be carried off.

Manures exposed to the weather lose much of their value At Cornell University manure was exposed from April 1 to September 1 — five months — with the following results:

	Value at Beginning per Ton	Loss per Ton	Loss (Per cent)
Horse manure . . .	$2.80	$1.74	62.0
Cow manure. . . .	2.29	.69	30.0

One factor in keeping down the fertility of the soil is the careless and wrong methods of handling manures (see Chapter IX).

4. *Inability to hold sufficient water decreases soil fertility.* — When soils have a tendency to bake and puddle after each rain,

it is an indication that the structure of the soil is not in good condition, due to a lack of organic matter and lime and, probably, to poor drainage. Such a soil will not hold sufficient water and will not give up the water that it does hold quickly enough for successful plant growth. By the addition of organic matter and lime, by proper drainage and tillage, and by employing a well-arranged system of rotation of crops, such a soil will be greatly improved in yielding its water supply to growing plants.

5. *Loss of nitrogen decreases soil fertility.* — Nitrogen is removed from the soil in four ways: (1) by plants; (2) by leaching; (3) by gaseous evaporation; and (4) by denitrification. Growing plants will prevent the leaching away of nitrogen, for the growing plant utilizes it as it becomes available; hence the value of cover crops. The odor one smells in handling fresh manure is ammonia, a compound containing nitrogen. Nitrogen is escaping in the form of ammonia gas.

Denitrification, due to improper drainage or lack of air in the soil, changes the nitrates into nitrites and sometimes completely into gaseous nitrogen. When nitrogen becomes gaseous or when it is in the form of nitrites, it can not be used by plants.

6. *Lack of bacteria in the soil causes it to respond in a decreasing way.* — Soil bacteria require the same conditions for growth that any other plants do, for bacteria belong to the plant kingdom. The conditions for their growth are: (1) food, composed mostly of organic matter in its various steps of decay and putrefaction; (2) proper temperature — bacteria thrive best at a temperature of 85° to 100° Fahr.; (3) free oxygen needed by the beneficial bacteria — however, there are bacteria that can live in the absence of free oxygen and that secure the oxygen from their foods; (4) proper moisture, that is, they prefer such amounts of moisture as we would find under ordinary field conditions, ranging from fifteen to thirty per cent.

Where there is a lack of bacteria because of an insufficient quantity of food, where the soil is cold on account of an excess of moisture, where air is excluded, or where the soil is too dry or too wet, we may rest assured that crops will not respond well, for the plant foods that are in the soil are not available. The soil lacks *active fertility* and we must establish conditions in which the soil bacteria thrive or we will likely find the soil *unresponsive.*

Summary. — Factors decreasing the fertility of the soil of the United States are: (1) soil erosion; (2) removing crops from soils; (3) loss of humus; (4) soil in a physical condition such that it will not hold a sufficient amount of water; (5) loss of nitrogen; (6) lack of soil conditions that foster bacterial growth.

LABORATORY EXERCISES AND HOME PROJECTS

1. Get specimens of soil from the top or slope of a hillside where it has been exposed to severe erosion and from the foot of a hillside where there was no soil erosion.

a. Study each soil as to color, texture, structure, composition, amount of organic matter, etc. Write your findings.

b. Fill a half-gallon jar with each soil. Plant wheat seeds in each, and grow plants for six or eight weeks. Write your findings.

2. Fill two one-gallon jars almost full of medium-fine sand. Add to one jar a quart of well-rotted organic matter (manure). To the other jar add a quart of similar vegetable matter except that the vegetable matter must not be in a well-decomposed condition. Plant wheat seeds in each, and record results about eight or ten weeks later.

3. Use two small plots near the schoolhouse; ten feet by ten feet will do. The soil should be prepared as farmers prepare soils for wheat sowing. Add to one plot half a gallon of fertilizer containing nitrogen. Add nothing to the other plot. Sow each to wheat. Write your observations every two weeks for at least three months.

4. Write an essay on "Losses of Plant Foods from the Soil."

CHAPTER VIII

IMPROVEMENT OF SOILS

Soil-improving agencies. — Some of the factors essential to maintaining and increasing the fertility of the soil are: (1) use of live stock upon the farm; (2) rotation of crops; (3) raising legume crops; (4) keeping up the humus supply; (5) maintaining good tilth; (6) preventing erosion; (7) correcting acidity of the soil; and (8) adding plant food by way of manures and fertilizers. (See Chapters IX, X.)

1. *Relation of live stock to permanent agriculture.* — The extensive depletion of many farms has been due to the fact that Burkett well states thus: "They sent the fertility away in bushel baskets, in ton lots, in bales, and nothing was returned to the soil." Any soil will become impoverished if crops are constantly being removed and nothing is returned. The table on p. 67 shows the loss of soil fertility based upon the nitrogen, phosphoric acid, and potash removed.

At first glance it would appear from this table that live stock remove as much fertility as grains do; but when we recall that it requires from ten to eleven pounds of corn or its equivalent to produce a pound of beef, and from five to six pounds of corn to produce a pound of pork, and when we recall also that about 80 per cent of the fertility ingredients in a feed are returned to the soil in the manure — that is, out of every five pounds of corn fed to hogs four are returned to the soil — we readily see the relation of animal husbandry to soil fertility. Burkett, in his "Feeding of Farm Animals," makes this excellent statement: "A farmer

selling hay sells, in the form of fertilizer value, one half as much as he received; if he sells pork, he receives twenty times as much for it as the value of the fertilizers contained in it; if milk, forty times; and if butter, one thousand times."

More than that, live-stock farming means a diversification of crops, and this protects the fertility of the soil.

2. *Rotation of crops tends to maintain soil fertility.* — No one holds that a mere rotation of crops will maintain or even help to build up or increase the fertility of the soil. For any crop grown and taken off a soil will take with it a certain amount of soil fertility in every ton of plants removed.

But that a rotation of crops protects the soil and serves as a buffer against impoverishment no one questions, for crop yields as shown by experimental evidences all point to the fact that rotation of crops does protect the soil. In other words, rotation of crops means: (1) we may till less acreage and get as large a yield; (2) less labor in production, but more harvesting; and (3) the fertility of the soil is protected.

Where rotation of crops is practiced some of the land is protected by grass, some by hay crops, some by deeply penetrating roots, and some by the stubble of harvested wheat and oat fields.

Rotation of crops has the following advantages:

(1) Different crops feed at different depths; hence they gather their plant foods from different strata of the soil. This rests the surface soil (Fig. 31).

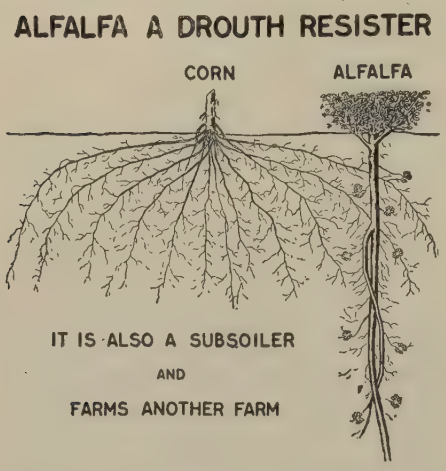
(2) Roots growing at different depths in the soil improve the physical condition of the soil — a very fundamental thing in helping to increase yields.

(3) Rotation of crops distributes labor. This gives more time to husband the soil.

(4) Decaying roots leave much humus in the soil. Grasslands leave the soil rich in humus, for they restore humus to the soil.

It has been found that timothy and redtop roots leave 7600 pounds of humus per acre.

(5) Rotations help to keep weeds out of the soil and hence leave the soil in better condition. Insects are also kept out. This helps to increase yields, for it is well known that insects destroy one tenth of our crops annually. Every rotation system should include a legume.



Courtesy of International Harvester Co.

Fig. 31. — **Root systems of corn and alfalfa**

Alfalfa roots penetrate 6 to 14 feet and deeper, gathering plant food and moisture from a soil layer never reached by corn roots.

3. *Leguminous crops maintain and protect the fertility of the soil.* — To quote Circular No. 38, Missouri Station: "In ordinary soils only about two thirds of the nitrogen supply of a clover plant comes from the air, the other third coming from the soil, so that when the tops are removed as hay, one is removing just about the proportion of nitrogen that came from the air, leaving in the root and stubble just about the amount that was taken from the soil. In taking off a clover crop, therefore, one is not building up the soil to any extent in nitrogen but about maintaining it. A man can put nitrogen into his soil through legumes at a cost of from three to six cents per pound, while if he bought the nitrogen commercially it would cost twenty cents per pound. The truck farmer is the only farmer who can afford to use any considerable amount of commercial nitrogen."

The clovers, soy beans, cowpeas, and alfalfa all have deep-penetrating roots, as shown in Fig. 31. This has a renovating effect upon the soil. It opens the soil to percolation, to soil bacteria, and to soil air, and all of these are conducive to the best soil conditions.

As the legumes balance the feed, or ration, so do they, when rotated with other crops, also balance the conditions controlling the amount of plant foods taken from the soil. Why do crops do well when following a legume? Because the legume has left the soil in a better condition — better physically and chemically.

A ton of manure from the legumes adds more fertility to the soil than does a ton from the cereals. Not only are the legumes good feed and renovators of the soil, but when fed they make superior manure.

4. *Keeping up the humus supply maintains fertility.* — All soils contain some organic matter in the form of decaying roots, stems, leaves, and animal life. The black color of the soil is due to decaying and decayed organic matter. In the last stages of decay this organic matter becomes humus. There is about 5 per cent of organic matter in average soils — often more in humid regions and less in arid sections.

Humus improves the soil as nothing else does. It makes a clay soil loose and porous, increases the water-holding capacity, prevents soil erosion, provides the best conditions for bacterial life, promotes chemical reactions, makes available plant foods in the mineral particles of the soil, and increases its workability.

The important question is, How may the humus content of the soil be maintained or increased? This may be accomplished by the following practices: (1) rotation of crops; (2) cutting wheat, oats, barley several inches higher and thereby leaving an extra amount of organic matter on the soil in the harvesting process;

(3) adding barnyard manures; (4) use of green-manure crops (Fig. 8); (5) letting weeds grow on bare spots and along places where water would erode the soil; and (6) growing and feeding the legume crops on the farm.

Fig. 32. — A field scene in Georgia

Peas are growing between the rows of corn. Such a practice tends to keep up the humus supply.

5. *Keeping the soil in good tilth maintains and increases soil fertility.* — Tilth increases the organic matter in the soil, for larger crops are produced. It is true that large crops take more plant foods out of the soil. The amount of materials in the cycle of life are simply greater (p. 39).

Courtesy of International Harvester Co.

Fig. 33. — Disking promotes good tilth

This illustration represents a highly efficient ratio of man power to horse power.

Good tilth permits a freer circulation of air and water through the soil — two essential features in crop yields. A soil in good tilth can be worked earlier in spring and later in the autumn than a soil of poor tilth — this is an important point in securing good crop yields. Good tilth improves the physical and chemical conditions of the soil. All these are important factors in plant growth.

6. *Preventing soil erosion is an important factor in maintaining soil fertility.* — Sloping lands are subject to soil erosion and the loss thus wrought is probably the greatest loss of our natural resources. It is important that both people and government should seek to prevent this waste.

Nature provides means which aid in preventing soil erosion. Nature's vegetation — grass, weeds, the mosses, and the quantity of humus they deposit in the soil — is a wonderful aid in preventing this loss. The roots of plants mat the soil together; the deep-penetrating roots make large openings in the soil. These large openings are water pipes through which the soil water escapes. The humus of the plants holds the water. Seldom are gullies seen on the steepest hillsides where forests are growing. The decayed leaves act as a sponge in taking up the rainfall. It is this excess water deposited and held in the winter which sustains the fine forests along the steep cliffs in the dry summers. Blue grass withstands floods and wind storms, holding the soil tenaciously intact. Weeds are not weeds when they are plants holding and improving the soil, for a "weed is a plant out of place," and weeds are not out of place when they are the sentinels and guardians of our soils. Weeds, grass, and trees are our friends, for they are helping in the improvement of our soils.

7. *Correcting acidity improves soils.* — There are a good many soils in the humid regions of the United States that are acid, or sour. The causes producing acidity of the soil are: (1) Lime is soluble and is therefore easily leached out by drainage water. (2) Lime is taken out of the soil by crops. (3) Some commercial fertilizers are acid. (4) Green plants when plowed under may cause acidity.

Some plants, such as red clover, alfalfa, and blue grass, will not thrive in an acid soil. In fact, they do best in soils that are slightly alkaline. On the other hand, some crops, like the potato,

crimson clover, alsike clover, soy beans, cowpeas, blackberries, and redtop are adapted to slightly acid soils.

To detect soil acidity, moisten a sample of soil and insert in it a strip of blue litmus paper. Within twenty minutes, if the soil

Courtesy of International Harvester Co.

Fig. 34. — Lime spreader in operation

This implement conserves man power and the operation is more efficiently performed because the lime is spread evenly and accurately.

is acid, the paper will turn red. Soil acidity may be corrected by adding lime to the soil. From one to three tons of ground limestone should be applied to each acre — depending upon the degree of acidity. Fifty-six pounds of quicklime and seventy-four pounds of water-slaked lime is equal to one hundred pounds of ground limestone.

In applying lime it should be remembered that it is soluble and it may be easily carried away by water. It is better to apply one ton of lime every year than three tons once in three years.

Courtesy of International Harvester Co.

Fig. 35. — Effect of lime on alfalfa in Wisconsin

One plot received an application of air-slaked lime at the rate of a ton per acre; the other received no lime. Both plots received six loads of manure per acre and were inoculated. Two cuttings, totaling 2080 pounds per acre, were produced on the lime plot, and only 1340 pounds on the unlimed plot. A ton of alfalfa contains about 100 pounds of lime.

There are lime spreaders on the market which may be purchased coöperatively by several farmers of a community, and they will be found more satisfactory in distributing the lime (Fig. 34). However, lime may be scattered broadcast.

The beneficial effects of applying lime to the soil, other than correcting acidity, are: (1) Lime improves the physical condition of the soil. It flocculates the soil particles; that is, lime causes them to group themselves into little clusters. It is said that one part of lime will flocculate and clear ten thousand parts of muddy water. Since the surface six inches of an acre of soil weighs about nine hundred tons, it is evident that one ton of lime will readily flocculate the soil particles of the average acre of land. (2) Lime, or calcium, is itself an essential plant food, which frequently is lacking in the soil. Most soils, however, have sufficient lime for crop growth. (3) Lime helps to unlock other plant foods, especially potassium and phosphoric acid. In this capacity lime is a very valuable soil amendment. (4) Lime aids in the chemical and bacterial processes in the soil. Bacterial life is fostered by lime, and the processes underlying nitrification demand a neutral, sweet soil.

Summary. — Permanent agriculture is dependent upon the fertility of the soil. It behooves us to husband the soil. Let us leave it richer than we found it in order that oncoming generations may have a better chance to "grow two blades of grass where only one grew before."

Some of the factors essential to maintaining and increasing the fertility of the soil are: (1) use of live stock upon the farm; (2) rotation of crops; (3) raising leguminous crops; (4) keeping up the humus supply of the soil; (5) maintaining good tilth; (6) preventing soil erosion; (7) correcting the acidity of the soil; and (8) adding plant food in the form of manures and commercial fertilizers.

LABORATORY EXERCISES AND HOME PROJECTS

1. Write a two-hundred-word essay, giving the causes of the low yields of some particular field in your neighborhood.

2. Secure several samples of soils. Soils from gardens and fields are preferred. Test each soil for acidity as directed in a preceding paragraph. Test some soils from fields that have grown corn for several years. Write your findings.

3. To a half-pint of some acid soil add a tablespoonful of lime. Add water and mix the two thoroughly. Test for acidity just as you did in Exercise 2. Write your findings. How may soil acidity be corrected?

4. In each of two gallon buckets or jars grow some plants. Probably some of the plants used in previous exercises may be employed for this exercise. Make a saturated solution of a quart of water and salt. Pour this on the soil in which one of the plants is growing. Repeat this for a few days; observe the results. How do you account for the results? Record.

CHAPTER IX

BARNYARD MANURE

Importance. — The value of farm manures has not been fully realized in the United States. Barnyard manures are the greatest means of maintaining the fertility of soils. The value of the manures produced annually in the United States is more than $2,500,000,000. Compare this with the value of three of our important crops:

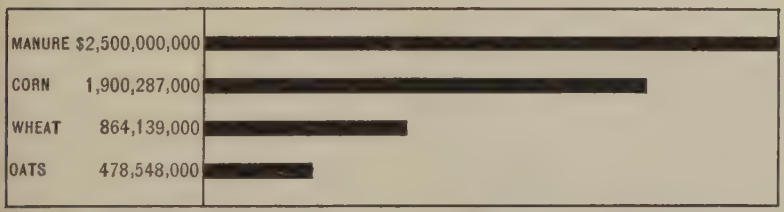


Fig. 36. — Value of manure compared with the cereal crops

The value of manure is equal to the poultry, dairy, swine, and sheep products combined. We see how important it is, then, to guard against the losses which may come to this important source of plant food.

Factors affecting the value of manure. — Aside from losses of manures due to exposure, which will be discussed later, most of

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: manure water, secured by soaking manure in water for 24 hours or longer; two one-quart tin cans.

the factors affecting the value of manures are: (1) kind of feed; (2) kind of animal; and (3) kind and amount of litter used.

It is evident that when feeds are used that are low in food value, the manure produced will have a low fertilizing value. On the other hand, if feeds are used that are highly nutritious, the manure produced will contain a high fertilizing value. To illustrate, if a steer is fed wheat straw alone, the manure voided has little value; but if good clover hay is fed, the manure voided has much greater value as a fertilizer. To bring out this point a little further, let us study the following table:

FERTILITY VALUE PER TON AND MANURIAL VALUE OF A TON OF FEEDING STUFFS

FEED	NITROGEN (Pounds)	PHOSPHORIC ACID (Pounds)	POTASH (Pounds)	FERTILITY VALUE	MANURIAL VALUE
Cottonseed meal, choice .	141.2	53.4	36.2	$34.51	$23.37
Wheat bran	51.2	59.0	32.4	16.64	11.77
Oat straw	11.6	4.2	30.0	4.71	3.42
Corn silage	6.8	3.2	8.8	2.20	1.56

The table shows the nitrogen, phosphoric acid, and the potash content in 2000 pounds of each feed. The fertility value is found by multiplying the number of pounds of nitrogen by 20, the number of pounds of phosphoric acid and potash each by 7 (cents), and taking the sum. Of course, the prices of the elements named vary. The manurial value is based upon the general fact that 65 per cent of the nitrogen and 80 per cent of the other fertilizing constituents of the feeds are recovered in the manure. The manurial value of a ton of cottonseed meal is $23.37, while the manurial value of a ton of corn silage is $1.56. From this it will be evident that the kind of feed used greatly affects the value of the manurial product.

The second factor that affects the value of manure is the kind of animal from which the manure is derived.

Composition of One Ton of Average Manure from Farm Animals

	Water (Per cent)	Nitrogen (Pounds)	Phosphoric Acid (Pounds)	Potash (Pounds)	Value
Sheep manure	68	19	7	20	$5.69
Horse manure	78	14	5	11	3.92
Cow manure	86	12	3	9	3.24
Pig manure	87	10	7	8	3.05
Chicken manure	88	32	32	16	9.76

Sheep and horse manures have a smaller water content and a higher nitrogen and potash content than the other manures named. This is the reason for their higher value. Sheep and horse manures are known as "hot manures," because they have great capacity for fermentation. Poultry manure has the highest fertilizing value.

And, finally, the kind of litter used affects the value of manure. Such materials as sawdust and wood shavings, when used as litter, add little, if any, fertility to manures. Wheat and oat straw add a great deal to the value of manure, and, where alfalfa or clover hay is mixed with the bedding, the manure is greatly enriched.

Amount of manure from different animals and its value for a year. — It has already been seen that the amount and value of manure depend upon the animal producing it. Swine eat about twice as much as does a horse and produce almost twice as much manure per one thousand pounds' live weight. Poultry eat more than twice as much as cattle in proportion to weight, and the manure voided is three times as great in value. The following

table shows the amounts and values of manures produced by different farm animals:[1]

MANURE PRODUCED PER ONE THOUSAND POUNDS' LIVE WEIGHT

	EXCREMENT PER YEAR (Tons)	MANURE WITH BEDDING PER YEAR (Tons)	NITROGEN PER YEAR (Pounds)	PHOSPHORIC ACID PER YEAR (Pounds)	POTASH PER YEAR (Pounds)	COST OF ELEMENTS IF PURCHASED IN COMMERCIAL FERTILIZERS
Horse . . .	8.9	11.9	128	43	103	$39.79
Cow	13.5	15.0	156	38	127	36.51
Sheep . . .	6.2	9.7	119	44	126	30.94
Pig	15.1	18.1	150	104	128	40.24
Fowls . . .	4.3	4.3	293	119	72	54.52

Another method of figuring the value of manure is to multiply the additional number of bushels of crop produced by the current price per bushel of the article produced. That is to say, if a ton of manure will increase the corn yield one hundred pounds and corn is worth 84 cents per bushel or $1\frac{1}{2}$ cents per pound, the value of the additional corn is $1.50. This may be considered the value of the manure for the first year. Of course the effects of manure upon the crops may be well seen for several years. Experiments have shown that for 10 years the average increase of crops produced by one ton of manure was valued at $3.44. If 50 cents per ton is allowed as a cost of applying the manure to the field, there still remains a handsome profit as a result of the application.

Relative value of liquid and solid manure. — The composition of the liquid and solid parts of manure is quite different. The liquid part contains much more nitrogen than does the solid part, and the solid part contains the greater part of the phosphoric

[1] Based on data from Henry and Morrison's "Feeds and Feeding."

acid and a very small part of the potash. The relative composition of the solid and liquid portions is as follows:

		Nitrogen (Per cent)	Phosphoric Acid (Per cent)	Potash (Per cent)	Value per Ton
Horse	Liquid manure	1.52	0.0	0.92	$7.36
	Solid manure	0.56	0.35	0.10	2.87
Cow	Liquid manure	1.05	0.0	1.36	6.10
	Solid manure	0.44	0.12	0.04	1.97

Courtesy of International Harvester Co.

Fig. 37. — Effect of manure with lime added

With manure only, production was 35.6 bushels; with limestone added, production was 49.3 bushels per acre. The lime and manure should be applied to the soil separately.

Liquid manure is worth about three times as much as solid manure for equal weights. Although the liquid excrement is

only about one third as much as the solid portion, its fertilizing value is about equal to that of the solid portion. The liquid manures are often lost. Such bedding as will absorb the liquid portion of the manure should be used. Straw and leaves are good absorbers and help especially to conserve the nitrogen which is so abundant in liquid manure.

Losses of manures. — The direct losses of manures are caused by leaching and by fermentation. Naturally liquid manures leach away unless absorbed by straw and litter applied to bedding. Often barns are built in such a place that the liquid portion of the manure drains away. If the liquid manure is lost, it is estimated that about half of the fertilizing elements are lost. Again, farmers often throw the manure out of the stables and allow it to lie for some time under the eaves of a building. This is just like taking paper money out of a bank and throwing it away (Fig. 38).

Fig. 38. — Bad farm practice
Manure exposed under eaves loses 30 to 60 per cent of its value.

From many experiments it is evident that manures lose much in a short period when exposed to rains and weather. The loss from twenty tons of manure so exposed is greater than the average profits produced under average conditions in the United States from an acre of corn.

The other cause for losses in manures is fermentation. Piled

manures, or even manures left in a stable, become hot and ferment. The odor about horse stables is due to the fact that fermentation is going on; the gas which we smell is ammonia. This ammonia contains the element nitrogen, and the manure is losing this valuable fertilizing constituent. It has been proved by experimentation that from 30 to 60 per cent of the nitrogen in a manure may be lost by fermentation. When a manure becomes hot because of processes of fermentation, its value is rapidly decreased.

Care of manure. — To get the best results out of manure, it should be scattered over the land as soon as produced. It should not be heaped in piles and later scattered but should be spread evenly over the soil when it is applied. Piling manures is an expensive way of applying them for two reasons: (1) It means an additional handling of the manure. (2) Its losses from leaching and fermentation are greater (Fig. 39).

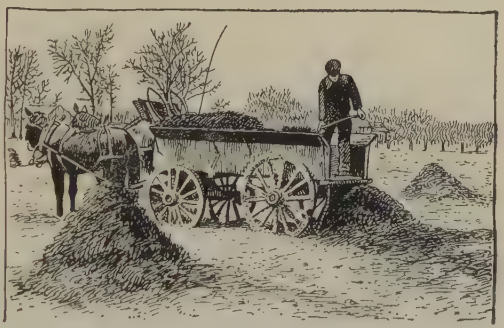


Fig. 39. — An expensive way to apply manure

Spreading manure directly by hand or with a manure spreader is the most economical method of handling it. Often, however, conditions are such that manure can not be hauled directly into the field or pasture on account of growing crops, soils being too wet, demands on labor, or weather conditions. It is for these reasons that every farmer should provide some protection for the manure. Well-covered sheds with a concrete floor and with concrete walls three or four feet high aid greatly in preserving the

fertilizing elements of manure. Manures stored in sheds should be kept moist and compact to prevent hot fermentations. The heating of manures is due to bacteria which require oxygen for their existence.

Green-crop manures. — Crops are sometimes grown for the purpose of plowing them under (Fig. 8). Such legume crops as red clover, alfalfa, soy beans, cowpeas, alsike clover, white clover, vetch, and rape and such grasses as barley, rye, wheat, and oats may be grown as a cover crop, used in the fall, winter, and spring and then plowed under. The legumes have the special value of deep-penetrating roots and of depositing atmospheric nitrogen in the soil. The grasses protect the soil and furnish a great deal of pasture.

Fig. 40. — A more efficient way of spreading manure

Van Slyke, in "Fertilizers and Crops," assigns the following beneficial effects to green-crop manures: "(1) They add organic matter; (2) conserve soluble plant food; (3) add nitrogen to the soil; (4) transfer plant foods from subsoil to the surface soil; (5) have a good effect on the bacterial life of the soil; (6) increase the plant foods; (7) improve the subsoil; (8) protect the surface soil; and (9) improve the structure of the soil."

Green-manure crops may be used to protect hillsides from erosion through the fall, winter, and spring. Cover crops protect and absorb the soluble plant foods. Soils that are depleted of nitrogen may be improved in that element by a legume cover

crop. Soils that are poor in tilth may be helped by the use of green-manure crops. These increase the yields of succeeding crops. Crops that are worth harvesting should not be plowed

Courtesy of International Harvester Co.

Fig. 41. — The best way of spreading manure

under but should be fed to some farm animals and the manure returned to the soil.

Summary. — The value of manure is not properly appreciated by the farmers of the United States. Its value is more than that derived from the corn crop. The value of the manure voided by animals weighing one thousand pounds is about $35 per year. Generally speaking, the liquid excrement is equal in value to

the solid excrement. The most economical method of handling manure is to distribute it evenly over the land as soon as it is produced. The manure spreader is an indispensable implement on farms where a large number of stock are kept. If manures can not be spread immediately after production, they should be stored in water-tight sheds and kept compact and moist, in order to protect them from losses due to leaching and fermentation.

LABORATORY EXERCISES AND HOME PROJECTS

1. Have pupils estimate the number of tons of manure produced on some farm. The manure contains about fourteen pounds of nitrogen, five pounds of phosphoric acid, and eleven pounds of potash per ton. The prices of the three elements as fertilizers may be had from the agricultural chemist of your agricultural college. For the purpose of this exercise you may allow nitrogen to be worth 20 cents a pound, and phosphoric acid and potash each to be worth 7 cents a pound.

2. Figure the amount and value of the manure produced by twenty cows and four horses, supposing that each animal weighs one thousand pounds. Fill an outline as follows and incorporate it in your notebook; make a similar outline for the actual number of live stock on your home farm or some farm with which you are familiar.

AMOUNT AND VALUE OF MANURE PRODUCED

KIND OF ANIMAL	NUMBER	NUMBER OF TONS PER YEAR	VALUE PER TON	VALUE OF MANURE

3. Let manure soak in water for about twenty-four hours. A quart cup of water with a small amount of manure will provide the manure water desired. Make holes in another quart can, and fill it almost full of soil. Now take some of the manure water, pour it on the soil, and let it

percolate through the soil. Catch some of the water percolating through in a glass tumbler. Compare the color of the water that passes through the soil with the manure water. Write your findings. What conclusions from the experiment may you draw regarding the absorbent power of soil? What is your opinion regarding the check on leaching of manure when it is spread over the land?

CHAPTER X

COMMERCIAL FERTILIZERS

Need for fertilizers. — All soils are not equally supplied with the elements of plant growth in the proportion which will produce crops to the best advantage. We have learned that the chemical make-up of soils depends upon their source of formation. Soils having a foundation of sandstone are different from soils built upon limestone mixed with some organic matter and from soils made almost wholly from vegetable matter, such as peat soils. (See tables, pp. 43, 106, 109, 112.) A peat soil generally contains nitrogen but is deficient in phosphoric acid and potash. Sand soils generally need nitrogen and phosphorus, and clay soils need nitrogen, phosphoric acid, and potash.

Stock and vegetable products are constantly being shipped to the cities, and the amount of fertility thus removed from the farm must be replaced by fertilizers (pp. 67, 72).

For this reason we go to the packing houses for the by-products obtainable from otherwise waste products of the slaughter of animals and turn them back to the soil and so maintain the soil fertility. Mines and factories also supply the three essential chemicals for plant growth — nitrogen, phosphoric acid, and potash.

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: samples of commercial fertilizers secured from a local dealer, from the packing houses, or from fertilizer dealers; six one-gallon jars or buckets; blue and red litmus paper.

Function of these elements in plant and animal growth. — This can be treated only in a general way here. Although each element is absolutely essential to plant or animal growth, each has a specific function.

Nitrogen promotes leafiness in plants. Green, luxuriant growth indicates a sufficiency of nitrogen. Often orchard trees

Courtesy of Ohio Experiment Station

Fig. 42. — Effect of fertilizer on orchards

have a great deal of foliage, which shows that an abundance of nitrogen is present in the soil (Fig. 42).

Phosphorus is found in some of the proteins; and since we find a greater amount of protein in the seeds than in the leaves and stems, it is thought that phosphorus plays an important part in seed formation. This element hastens root and stem growth, and especially seed growth, and for that reason hastens

maturity, an important factor often in getting maximum yields.

Potassium seems to assist in the formation of starch and sugar. Dr. Hall, director of the Rothamsted Station, reports the following on the effect of potash on leaf, root, and sugar production in mangels.

Effect of Potash on the Production of Mangels

Treatment	Leaves per Acre (Tons)	Roots per Acre (Tons)	Sugar per Acre (Tons)
Ammonia salts and phosphates applied	2.95	12.00	0.8
Ammonia salts, phosphates, and potash applied	3.25	28.95	2.2

The sugar content more than doubled when potash was applied.

In animal bodies nitrogen helps in making bones, tendons, muscles, and other tissues. Phosphorus makes up a large part of the bones, ninety per cent of bone being lime and phosphorus. Potassium aids also in bone formation and other processes.

Commercial fertilizers only a drop in the bucket. — How much plant food is usually added by way of commercial fertilizers per acre? If 200 pounds of fertilizers containing 0.8 per cent available nitrogen, 8 per cent available phosphoric acid, and 2 per cent available potash were added, there would be added 1.6 pounds of nitrogen, 16.0 pounds of phosphoric acid, and 4.0 pounds of potash to the acre. This amount of plant food added to any kind of soil adds only an insignificant trifle of plant foods to those that are already in the soils.

Again, if we compare the amount added of each element in the fertilizer with the amount removed by a crop, we find similar results. This is especially true of the nitrogen. The addition of 200 pounds of such a fertilizer adds only a small per cent of

the nitrogen taken out by a ton of dent corn. There would be added 1.6 pounds of nitrogen and a ton of corn removes 32.4 pounds. Therefore, we can not attribute the additional yields to any extent to the nitrogen in the fertilizer.

Courtesy of Purdue Experiment Station

Fig. 43. — Effect of fertilizer added to lime

Lime was not sufficient to produce efficient yields in this test at the Scottsburg (Indiana) Experiment Field. Lime alone produced 30.3 bushels of corn per acre (right). When 300 pounds of complete fertilizer were added, the yield was 72.3 bushels per acre (left).

If the 200 pounds of fertilizer adds 16.0 pounds of phosphoric acid and corn removes only 13.8 pounds per ton, the amount of phosphoric acid added equals approximately the amount of phosphorus removed. The 200 pounds of fertilizer described adds only 4 pounds of potash, which is about one half of what a ton of corn removes per acre.

If such a fertilizer does any good at all, it must be due to the phosphoric acid, and not to the potash, for the potash was approximately only what the crop needed yearly. That the use of phosphoric acid in crop production has given economic returns is substantiated by extensive experimental evidence. The use of nitrogen and potash has not given such good returns, although exceptions to the statement may be quoted by people who are interested more in commercial sales than in economic crop yields.

Kinds of commercial fertilizers. — There are three elements from which fertilizers are named. These elements are nitrogen, phosphoric acid, and potash; and we have nitrogenous, phosphate, and potassium fertilizers. Usually each fertilizer contains all three elements mentioned. The source and composition of different kinds will be briefly discussed.

Nitrogenous fertilizers. — Besides the nitrogen added to the soil by leguminous crops and barnyard manures, there are two sources from which the nitrogenous fertilizers are supplied — the slaughter houses and mines. The slaughter houses provide dried blood, tankage, and bone meal. These have about the following fertilizing constituents in them per ton:

	Nitrogen (Pounds)	Phosphoric Acid (Pounds)	Potash (Pounds)
Dried blood	260–280	10–20	0
Tankage	80–240	30–120	0
Steamed bone meal . .	20–30	560–600	0

Since these fertilizers contain much nitrogen, they are expensive. Sodium nitrate, or Chile saltpeter, which contains nitrogen, is mined in Chile and Peru. It contains from 15 to 16 per cent

of nitrogen. As it is very soluble, it should be applied only where it will be used immediately by plants.

Phosphate fertilizers. — The phosphate fertilizers are derived from dissolved phosphate rock, bone meal, and tankage. In some parts of the United States there are natural deposits of rocks that contain phosphates in combination with lime. These rocks are ground and treated with sulphuric acid, which unites

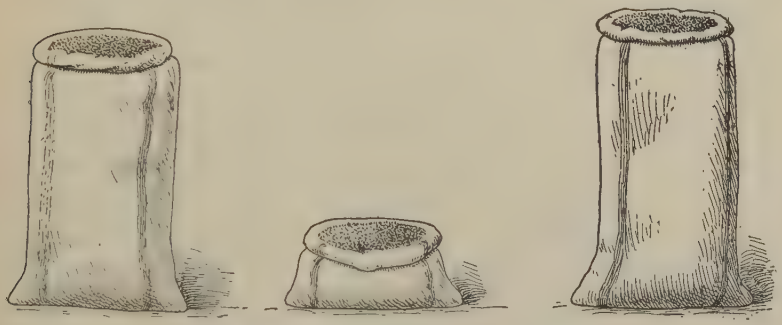


Fig. 44. — Effect of fertilizer on wheat

At left, 21.3 bushels per acre, with dried blood, 60 pounds, and phosphate 200 pounds per acre; in middle, 4.2 bushels per acre, with no fertilizer; at right, 22.6 bushels per acre, with acid phosphate, 200 pounds, and muriate of potash, 30 pounds per acre.

with the lime and makes the unsoluble phosphorus soluble, a form in which it is available to plants. The product is called acid phosphate; it contains about 15 to 20 per cent of soluble phosphorus.

Bone meals contain both nitrogen and phosphorus. They are sold either as raw bone meal or steamed bone. Raw bone meal is freshly ground bone. The ground bone is then steamed. The steaming removes some of the nitrogen and fat from the bone. It contains about 1 per cent of nitrogen and 11 per cent of phosphorus.

Potassium fertilizers. — The four forms of potassium fertilizers most commonly used are potassium chloride, potassium sulphate, kainite, and wood ashes. Kainite is a potassium fertilizer mined in Stassfurt, Germany, and is used in the manufacture of most of the potassium fertilizers. The supply of kainite at these mines is said to be inexhaustible. Potassium chloride is a manufactured product; it contains about 45 to 50 per cent of potassium. Potassium sulphate is made from kainite; it contains about 45 per cent of potassium. This form of potassium fertilizer is used for fertilizing potatoes. Wood ashes contain from 2 to 8 per cent of potash, which is very soluble and leaches away easily. Wood ashes make a valuable fertilizer and should be carefully saved.

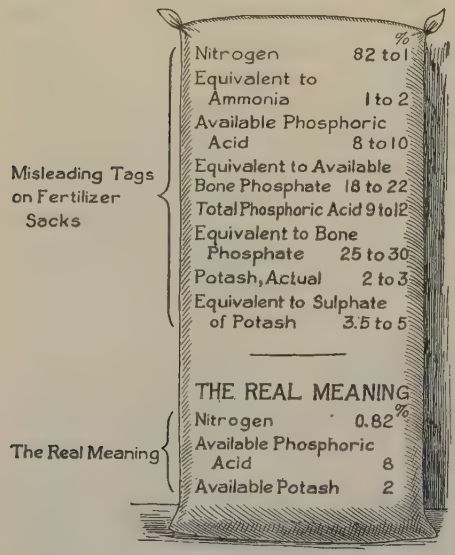

Misleading Tags on Fertilizer Sacks
The Real Meaning
%
Nitrogen 82 to 1
Equivalent to Ammonia 1 to 2
Available Phosphoric Acid 8 to 10
Equivalent to Available Bone Phosphate 18 to 22
Total Phosphoric Acid 9 to 12
Equivalent to Bone Phosphate 25 to 30
Potash, Actual 2 to 3
Equivalent to Sulphate of Potash 3.5 to 5
THE REAL MEANING
Nitrogen 0.82%
Available Phosphoric Acid 8
Available Potash 2

Fig. 45

Value of commercial fertilizers. — The value of a fertilizer depends upon its nitrogen or ammonia, phosphoric acid, and available potash content. All other materials in a fertilizer are worth little or nothing and are known as "filler." In order to mislead purchasers of fertilizers, meaningless statements are put on fertilizer bags. (See Fig. 45.)

There should be a Federal law compelling fertilizer companies to label bags of fertilizers correctly without adding a lot of

meaningless terms and statements printed on the sacks to mislead the purchaser.

Price of commercial fertilizers. — The price of fertilizers is based upon the nitrogen, phosphoric acid, and potash contained in them. The prices of these elements vary in different sections of the country and change just as the price of any other commodity changes. To figure the real money value of a commercial fertilizer, multiply the number of pounds of nitrogen by 20 and the number of pounds of available phosphorus and potash, each by 7, and add the results. This will be the approximate value of the fertilizer. For example: A ton of the above fertilizer, which contains 0.82 per cent nitrogen, 8 per cent available phosphoric acid, and 2 per cent available potash, will contain 16.4 pounds of nitrogen, 160 pounds of phosphoric acid, and 40 pounds of potash. Then to find the value of each we have:

$$.20 \times 16.4 = \$\ 3.28 \text{ value of nitrogen}$$
$$.07 \times 160 = \ 11.20 \text{ value of phosphoric acid}$$
$$.07 \times 40 = \ 2.80 \text{ value of potash}$$
$$\text{Total} = \$17.28$$

Such fertilizer is worth about $17.28 per ton. It is, of course, quite likely that we should allow some additional cost for freight. The price of any fertilizer may be figured in a similar manner. For the current prices of the elements in fertilizers write to your State Agricultural College.

How to determine what fertilizer to use. — There is no very definite way of determining what fertilizer to use, because kinds of soils, seasons, and different varieties of plants have different requirements. The information that one gains from the production of each crop should help in the successful production of the next. Information should be asked from the Agricultural Experiment Station and from agricultural experts. It has been suggested by some authorities that field plot studies be made.

This undoubtedly is the best method of determining approximately what elements to use. But even if the same fertilizer and the same crop are used, the function of the fertilizer will be affected to a considerable extent by the season.

Fig. 46. — Test fields at the North Dakota Experiment Station

State Agricultural Colleges and the United States Department of Agriculture greatly aid the farmer by dissemination of the results of their researches and experiments.

In general it may be said that nitrogen promotes leafiness and phosphoric acid and potash help in seed formation. Leguminous crops generally respond to phosphoric acid, potash, and lime. Potatoes need an abundance of potassium. Oats, wheat, rye, and corn generally need all the elements of a commercial fertilizer.

Another important point to consider in the use of commercial

fertilizers is the kind of farming practiced. In trucking, when the value of the crop is $100 to $150 per acre, it may be economic to use $10 worth of fertilizer, but the same amount of fertilizer on an acre of timothy would usually result in loss.

Mixing of fertilizer at home. — After it has been determined what elements are needed, fertilizers can be easily mixed in the proper proportions by the farmer. For just as the ingredients of a chicken feed are raised in price when mixed, so also are the elements that go to make a fertilizer raised when mixed by the manufacturer. Oats, corn, and wheat, when mixed, often sell for 3 to 4 cents a pound, when no one of them is selling for more than $1\frac{1}{2}$ cents a pound when sold alone. Home mixing also has the advantage of enabling the farmer to know what elements are in the fertilizer. By knowing this he can more nearly meet the requirements of the crop and soil conditions. Home mixing of the elements of commercial fertilizers is recommended as being good farm practice.

Application of fertilizer. — If commercial fertilizers are used, it may be well to employ the following suggestions:

1. The fertilizer should be placed in the hill where the plant is to grow so that it may be used the same season; otherwise much of it may leach away.

2. Commercial fertilizers bring better returns on rich than on poor soils. Warren states: "It does not pay to put commercial fertilizer on poor land. Such land usually needs humus, and must be treated before it will pay to use fertilizers. About forty farmers in New York have reported trials of nitrate of soda for the production of timothy hay. In very few cases has it paid if the field did not yield at least one and one-fourth tons when untreated, and in very few cases has it failed to pay when the unfertilized acre yielded over one and one-fourth tons. It seems to be very nearly as easy to double a yield of one and one-

half tons as to double a yield of one-half ton. In the former case the gain will be three times as much as in the latter."

3. The use of commercial fertilizer may pay well in truck farming. That is, if the value of the crop is $100 to $200, a ton of fertilizer, the price of which is $30, may yield $20 of net profit. If the same amount of fertilizer were applied on poor soils on an oat or timothy crop, the loss would likely be about $20.

Barnyard manures, green-manure crops, the use of legumes, and crop rotations are, however, the easiest and cheapest means of maintaining soil fertility.

Summary. — There are soil conditions where the use of commercial fertilizers will prove economic. The three essentials of a commercial fertilizer are nitrogen, phosphoric acid, and potash, upon which the value and price of commercial fertilizers are based. The nitrogenous fertilizers are furnished by the packing houses, in the form of dried blood, bone meal, and tankage. Nitrate of soda is mined in Peru and Chile. Nitrogen is worth about 20 cents per pound in fertilizers. Phosphate fertilizers come from rocks, treated with sulphuric acid, and bone meal. Potash comes mainly from Stassfurt, Germany. Phosphoric acid and potash are worth about 7 cents per pound. Commercial fertilizers should be supplemented by manures and good farm practices.

LABORATORY EXERCISES AND HOME PROJECTS

1. Secure as many samples of commercial fertilizers as possible from a local dealer or elsewhere. Study these fertilizers (1) as to composition, (2) as to their source, and (3) as to their color, texture, and odor.

2. Fill six one-gallon jars or buckets with black loam. To one add 8 grams of a nitrogen fertilizer, containing about 2 to 3 per cent nitrogen; to another add 8 grams of a fertilizer containing about 8 per cent available phosphoric acid; to a third add 8 grams of a potassium fertilizer containing

about 3 per cent available potassium; to the fourth jar add 8 grams of lime; to the fifth add 4 grams of each of the above ingredients, and to the sixth add nothing. Plant eight to ten grains of wheat in each jar. Maintain conditions for growth for ten or twelve weeks. Record results.

3. From the guaranteed analyses of three or four commercial fertilizers, figure their value, assuming that nitrogen, available phosphoric acid, and available potash are worth 20 cents, 7 cents, and 7 cents respectively.

Note. — No hasty conclusions should be drawn from this experiment. Fairly accurate conclusions can only be made when an experiment is continued over several years and crops are grown to maturity under field conditions.

4. Test about six samples of commercial fertilizers for acidity and alkalinity with litmus paper. Record results as follows:

Kind of Fertilizer	Alkali or Acid

Note. — If blue litmus paper turns red, it shows acidity. If red litmus paper turns blue, it shows alkalinity.

CHAPTER XI

MANAGEMENT OF DIFFERENT KINDS OF SOILS

Classification of agricultural soils. — Based upon texture and upon organic content there are at least four types of soil: sandy soils; black loam soils; clay soils; and marsh soils.

Sandy soils. — Sandy soils vary in their composition, but, in general, may be thought of as having the following amounts of the different soil separates: sand, from 25 to 56 per cent; silt, from 10 to 30 per cent; clay, from 5 to 15 per cent. Soils made up wholly of sand have little, if any, agricultural value, except in rare cases where the seasons are suitable and where they are located near a good market. In such cases they may be improved by the addition of manure and fertilizers so that they will produce some of the truck-garden products.

Composition per Acre of the Upper 7 Inches of Sandy Soils

	Nitrogen (Pounds)	Phosphorus (Pounds)	Potassium (Pounds)
Sand	1675	620	39,750
Sandstone	1700	380	7,840
Light sandy upland	1100	250	2,100

It will be seen that sands are deficient in the essential elements of plant foods, for a well-balanced soil contains more of each of the plant foods than the above table shows.

There are four defects of sandy soils: (1) They are too porous, permitting percolation too readily. (2) They permit air circulation too freely. (3) They do not hold plant foods in the form

of organic matter. (4) They lack in the mineral requirements of plant foods. Each of these disadvantages of sandy soils will be briefly discussed and remedies suggested.

1. *Sandy soils are porous.* — They will not naturally hold sufficient water for plant growth. This can be overcome to a considerable extent: (1) by adding humus to the soil, humus having at least $6\frac{1}{2}$ times the water-holding capacity of sand; (2) by rolling and dragging the soil, a process which compacts the soil and thus excludes the free circulation of the air; (3) by the maintenance of a soil mulch, which may be done by cultivating the upper two inches with any implement that will keep it loose.

2. *Sandy soils permit the air to circulate too freely.* — Although this makes a sandy soil an early soil, yet the air dries the soil unduly and has a tendency to oxidize, or burn out, the organic matter. Crops that mature in midsummer can scarcely be naturally matured by sandy soils because they burn up for lack of water. Sandy soils produce only early-maturing or drought-resisting crops.

3. *Sandy soils do not hold the organic plant foods well.* — The water passes through these soils so rapidly that plant foods leach out. Following closely the suggestions of the above two paragraphs will help to prevent leaching. Winter cover crops, such as rye, wheat, etc., help in holding the plant foods intact. Some organic matter may be occasionally added by growing a green-manure crop and plowing it under. (See Fig. 8.)

4. *Sandy soils are deficient in the mineral ingredients of plant foods.* — Pure sands do not contain any of the essential plant foods; whatever plant foods are found in a sandy soil are there because of the presence of clay, silt, and organic matter. A sandy soil needs nitrogen and phosphorus and some potash. These may be added in the form of commercial fertilizers.

5. Truck crops, vegetables, strawberries and other berries, potatoes, sweet potatoes, beans, and legumes are adapted to sandy soils. Early-maturing varieties may prove most profitable.

Black loam soils. — Black loam soils, which are classified as clay, silt, sandy, and gravelly loams, contain a fairly well-balanced mixture of silt, clay, and various grades of sands. The different classes of loam soils are due to the different proportions of silt, clay, sand, etc. found in them. The loam soils have a texture, a structure, and a water-holding capacity which renders them fairly easily worked, and at the same time they have a high percentage of the essential elements, both organic and mineral, to supply the needs of plants. They are the soils most commonly found in the farming areas of the United States.

Fig. 47. — A fine stand of corn
Black loam soil furnishes the plant food that this heavy-feeding crop demands.

The average black loam soil is a well-balanced soil in its virgin state and, if properly handled by rotation of crops, by addition of manures, and by proper tillage, it may be kept in a high state

of fertility for an indefinite time. Such a soil will respond to good farm practices even more readily than sandy or clay soils. The black loam soils are adapted to the cereals, legumes, and almost every crop grown, provided the seasons are favorable (Fig. 47).

Clay soils. — Clay soils contain from 20 to 50 per cent of clay. A clay soil has the following textural composition:

1. Clay	50 per cent
2. Silt	30 per cent
3. Very fine sand	12 per cent
4. Fine sand	5 per cent
5. Medium sand	2 per cent
6. Coarse sand	1 per cent
7. Gravel	0 per cent

The chemical composition of different clay soils is as follows:

Composition per Acre of the Upper $7\frac{1}{2}$ Inches of Some Clay Soils

	Nitrogen (Pounds)	Phosphorus (Pounds)	Potassium (Pounds)
Clay	3250	5600	12,600
Black clay loam	7380	2600	61,000
Drab clay	5800	1900	48,000

The black clay loam soils are richer, generally speaking, in all the mineral ingredients than sandy soils.

The small particles of a clay soil make it hard to cultivate. Clay soils have the following features, which are in some instances disadvantageous: (1) They are so tight that they do not drain easily. (2) They are often cold soils. (3) They puddle easily. (4) They are often deficient in phosphorus. How these deficiencies in clay soils may be improved will be discussed in the following paragraphs:

1. *Clay soils do not drain easily.* — A two-inch rain will percolate away readily in a sandy soil; but, if a two-inch rain falls upon a clay soil of close texture in a short period, most of the water will drain off by surface drainage. It is for this reason that

Courtesy of International Harvester Co.

Fig. 48. — Mowing alfalfa

This plant will thrive both in black loam and in clay soil. In the latter its deep-penetrating roots render the soil more porous.

a clay soil erodes easily. Surface and underground drainage will aid in protecting clay soils. These soils, especially sloping clay soils, should also be protected with grass. Clay soils hold the water well. This is true especially when a soil mulch is maintained.

2. *Clay soils are often cold soils.* — They retain the soil water so persistently that they do not warm up readily in the spring. Drainage, the addition of organic matter, and fall plowing will overcome this to some extent.

3. *Clay soils puddle easily.* — They can not be plowed when the least bit wet. A clay soil forms a solid crust after each rain. This shows a poor structure. This may be overcome by adding organic matter, by leaving stubble on the soil, by adding barnyard manure, or by plowing under a green-manure crop occasionally. The addition of lime will help to improve the structure. The growing of crops, like alfalfa, with deep-penetrating roots will help to make the soil more porous (Fig. 48).

4. *Clay soils are often deficient in phosphorus.* — They are usually rich in potassium but lacking in phosphorus and, sometimes, in nitrogen and lime. The phosphorus may be supplied by the addition of *floats* or other forms of commercial fertilizers. Nitrogen can be most easily supplied by the growing of leguminous crops. Peat is found in some localities, and it may be applied to clay soils to furnish nitrogen.

The grasses, such as blue grass, redtop, corn, wheat, oats, barley, and rye are especially adapted to clay soils. The shallow-rooted grasses prefer a compact soil, one exposing a lot of soil surface to the roots and one holding a good deal of moisture. The looser clay soils will also produce legumes, especially soy beans and cowpeas.

Soils of organic formation. — Peat, marsh, and muck soils are all the result of deposits of plant remains. A peat soil is made up of organic matter, in which the plants have not undergone complete decomposition. In muck soils the organic matter shows greater decomposition. In marsh soils the organic matter is thoroughly decayed.

The composition of a few of these soils follows:

PLANT FOODS PER ACRE IN THE UPPER 7 INCHES OF SURFACE SOIL

	NITROGEN (Pounds)	PHOSPHORUS (Pounds)	POTASSIUM (Pounds)
Peat	8,000	340	1100
Marsh	21,000	2800	2560
Muck	18,000	600	

These soils contain an abundance of nitrogen but are usually deficient in phosphorus and potassium.

Marsh, muck, and peat soils are of organic formation and are therefore very black in color. These soils have the following deficiencies: (1) They often lack drainage. (2) They are generally acid. (3) They lack phosphorus. (4) They sometimes lack lime. These points will be discussed:

1. *These soils often lack drainage.* — Being formed in swamps, lakes, and lowlands, they are wet soils. More than that, the soil particles are very small, and, of course, this prevents the free passage of water through them. Surface and underground drainage often makes them very productive (Fig. 25).

2. *These soils are often acid.* — The acidity is caused by the formation of humic acids during the processes of decay. Since these soils are often deficient in lime, ground limestone may be added to good advantage. This corrects the acidity and overcomes the deficiency.

3. *These soils are usually deficient in phosphorus.* — Often only 200 to 300 pounds of phosphorus per acre are found in the tillable surface soil, and this is insufficient to produce average crops. For it will be remembered that only a small amount of the plant food in a soil is available to plants. Hopkins states, "We can assume for a rough estimation that the equivalent of two per cent

of the nitrogen, one per cent of the phosphorus, and one fourth of one per cent of the total potassium contained in the surface soil can be made available during one season by practical methods of farming."

The fact of it is that the roots of plants come in contact with but a small fractional part of the soil, and it will be evident, if Hopkins' statement is true, that less than five pounds of the phosphorus would be made available for plants in one season. For this reason phosphate fertilizers must be added to muck, marsh, or peat soils to get economic returns.

Potassium likewise is often deficient in these soils, as is shown by the table (p. 112).

4. *The hay crops* are best suited to marsh lands, but when these soils are well drained they become the most prolific soils in the production of almost all crops (Fig. 27).

Summary. — Soils of various types—sandy, clay, black loam, and marsh soils — vary in texture, composition, and structure, and therefore deserve careful study. Crops adapted to each soil will bring best returns. The needs of one will not suffice for another. Although the suggestions given in this chapter and in previous chapters are helpful, they are still inadequate, for at best they can only be general in their application. Your State Experiment Station, your county farm agent, or the soil survey map of your county will give additional data. (Not all counties have such a survey. Only about 1850 counties have been surveyed, 1923.)

LABORATORY EXERCISES AND HOME PROJECTS

1. Fill a long tube with sandy soil and determine how long it will take for water to pass through it. Then add a lot of clay to the sandy soil and determine how long it will take water to pass through it.

2. Discuss how a clay soil may be made more porous, how a sandy soil may be made more compact, or how sandy soil may be tied together.

PART TWO

CROPS

The results of breeding high and low ears

CHAPTER XII

IMPROVEMENT OF PLANTS

Why plants are improved. — De Candolle, a Swiss botanist, in his book entitled, "Origin of Cultivated Plants," enumerates 247 species of cultivated plants known to man. Of the 247 plants cultivated by man about 45 species have been in domestication for over 4000 years. Wheat, barley, rye, oats, millet, rice, flax, hemp, cabbages, onions, grapes, apricots, peaches, pears, apples, olives, figs, dates, and bananas belong to these old plants that have been cultivated for thousands of years. There are many plants of more recent origin and development.

The domesticated plants feed, clothe, and shelter mankind. We can gather some food from wild plants even at the present time. Persimmons, blackberries, wild strawberries and gooseberries, pecans, plums, crab apples, pawpaws, black haws, wild onions, and other plants would furnish some food; but if we should have to depend upon wild plants and wild animals for food, the human race would be rapidly reduced in number by famine, and it is likely that the origin and history of plant development, animal origin and development, and in fact much of the history of different nations would have to be repeated.

The prolificacy of corn (Indian maize), yielding an average of about 30 bushels per acre and even as high as 232.7 bushels per acre, represents the improvement made in this plant since America was discovered, because corn is of American origin. It was first found growing by the Spaniards upon their discovery of the Aztec Indians. It is traditional that the Aztecs had grown

Fig. 49. — Ear of pod corn
The ancestor of improved varieties.

corn as far back as the time of Christ. And no one knowing the history of corn could do less than pay the highest tribute to the Indians, who developed corn up to the stage where it could be taken up by the more progressive white race and developed until it now furnishes more pounds of dry food than all other cereals combined. All of the wild plants of the world would not produce so much food as Missouri alone can produce from the wonderful plant *corn*.

There are probably more than 247 useful domestic plants now. A thornless cactus grows on the arid plains of the West, and it is likely that a plant producing fine rubber-making material may be developed. Botanists and the Experiment Stations seek continually to introduce new plants that may be of use and to improve old ones.

We all like plants. As we travel through a country, we enjoy the beautiful fields of grain, the green pastures, and the magnificent forests. We do not like the desert with

Photo by W. E. Hinds

Fig. 50. — Corn ear showing tip well covered by shuck
The result of methods of improvement.

its waste and barrenness. The people of the world spend millions of dollars to push back the deserts in order that beautiful and useful plants may be grown.

Why then do we improve plants? We improve plants so that man may be continuously and comfortably fed, clothed, and housed. And in addition to this we produce many plants for their beauty and attractiveness and for the shade and comfort they provide.

Need for further improvement of plants. — The population in the United States in 1880 was, in round numbers, 50,155,000, but in 1920 it was 105,710,000. That is, during this 40-year period our population more than doubled. It is true that we have only about 35 people per square mile; while in England they have 670; in Belgium, 658; and in The Netherlands, over 500. We must continue to feed an ever increasing population.

It is probably a conservative estimate that our farmers are now producing 20 to 25 per cent more of the important farm crops and farm animals than we now use. This, of course, varies with different plants and animals. From 20 to 40 per cent of our wheat crop is exported, and 40 to 50 per cent of our cotton. About 15 per cent more potatoes are produced than are needed generally although occasionally there is a shortage. We export considerable quantities of beef and pork and a small amount of dairy products.

Improvement of wheat. — Wheat is the most important food crop grown. Some varieties are much more prolific than others. At the Indiana Station the six lowest-yielding varieties produced an average of 21.9 bushels per acre; and the six best-yielding varieties produced an average of 31.8 bushels per acre. A difference in yielding ability of 9.9 bushels per acre is great; if the total yield in the United States were reduced proportionately,

the yield for the year 1922 would have been 558,985,000 instead of 810,123,000 bushels.

The average yield of wheat in the United States is about 14 bushels per acre, with a high yield of 117 bushels per acre on 18

From Ladd's Dairy Farming Projects

Fig. 51. — A field of lodged grain

By selection varieties of grain with stiffer straws are being developed; this improvement will eventually reduce the loss from lodging.

acres. To produce 117 bushels of wheat per acre requires that all factors of production be present, including prolificacy.

Plants are acclimated or made adaptable to certain climatic conditions. There are eight well-defined wheat districts, and each district is adaptable to particular varieties of wheat. Durum

wheat, introduced in 1899 from Russia and especially adapted to arid regions, now produces a crop valued at $50,000,000 annually.

Wheat has been improved in the stiffness of the straw. This prevents its being blown down, or lodging. When wheat lodges, it does not mature well, and much of it may become moldy and decay. Thousands of dollars of losses are sustained annually because of lodging; and while much improvement has been made, doubtless work along this line will be continued (Fig. 51).

Black stem rust which attacks wheat, oats, barley, and rye is one of the most destructive diseases of these plants. There are several kinds of rusts, but the black stem rust does the most damage.

In early spring the barberry is infested with the fungi of this disease. For this reason the Federal government is spending much money to eradicate the barberry. The first annual appropriation, in 1918, was $150,000; and in 1922 this was increased to $350,000 annually. More than five and a half million barberry bushes have been destroyed. European countries have for years attempted to destroy the barberry plant, and in Denmark the campaign has been so successful that black stem rust is almost unknown. Like the European countries we must outlaw the barberry. Thus we can increase our wheat yield and help to feed an ever increasing population.

Improvement of corn. — What is desired in corn is to get the greatest number of pounds of corn with the highest amount of protein content possible. The Indians produced a corn having ears with 150 to 200 poorly developed kernels. The largest ears they produced weighed about two ounces. To-day 120 average ears make a bushel. That means that the average ears weigh 8 ounces, and there are ears that weigh 16 ounces. Corn

has been increased in shelling capacity at least 800 per cent since the discovery of America.

The chemical composition of corn may be changed to some extent. Thus at the Illinois Station[1] the following change in protein content was secured in 27 years by starting in 1896 with seed coming from the same ear:

CHANGE IN PROTEIN IN CORN DUE TO VARIATION AND SELECTION

	HIGH-PROTEIN PLOT	LOW-PROTEIN PLOT	DIFFERENCE IN CROPS HARVESTED
	Average per cent of crop harvested	Average per cent of crop harvested	
1896	10.92	10.92	0.00
1897	11.10	10.55	0.45
1898	11.05	10.55	0.50
1899	11.46	9.86	1.60
1900	13.32	9.34	3.98
1901	14.12	10.04	4.08
1902	12.34	8.22	4.12
1903	13.04	8.62	4.42
1904	15.03	9.27	5.76
1905	14.72	8.57	6.15
1906	14.26	8.64	5.62
1907	13.89	7.32	6.57
****	****	***	***
1917	14.44	7.08	7.36
1918	15.48	7.31	8.17
1919	14.70	6.46	8.24
1920	14.01	7.54	6.47
1921	16.66	9.13	7.53
1922	17.33	7.41	9.92

The oil content of corn may likewise be changed through selection. According to the publication above quoted, the oil content was increased from 4.7 to 7 per cent for the high-oil plot, and decreased to 2.59 per cent in the low-oil plot. Since from 80 to 85 per cent of all the fat is in the germ, growing corn with a larger

[1] Missouri State Board of Agriculture Report, 1909.

germ increased the proportionate part of oil. Professor Hopkins[1] found that if a higher starch content in corn is desired, it may be secured by breeding for low protein and oil.

Whether it is desirable to have corn with a high protein and oil content or with a high starch content depends on the use to which it is to be put. A corn rich in protein is preferred for horses doing hard muscular work, particularly in the Corn Belt, where other feeds furnish the necessary carbohydrates. In the South, however, where other feeds, such as cowpea hay and cottonseed products, are lacking in carbohydrates, a corn with a higher starch content is preferred. Corn for the manufacture of starch or glucose should, of course, be rich in starch.

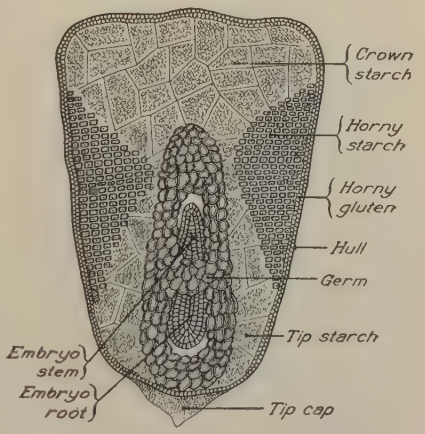


Fig. 52. — Low-protein corn kernel
Compare with Fig. 53.

The hard flinty sides of the kernel contain a greater proportion of protein. Therefore to breed for corn having this part of the kernel developed increases the proportion of protein and reduces the amount of starch. This is helpful in making corn a better feed for growing and working animals.

The kind of stalk and the height at which the ear appears, also, are points to be watched in corn improvement. A short, stocky stalk is preferred, and ears should not grow too high on the stalk. At the Illinois Station, starting from the same seed, in six years

[1] Illinois Bulletin No. 87.

two kinds of corn were developed; one bore its ears on an average of four feet above the ground, and the other on an average of only two feet above the ground.

The improvement already made in securing varieties of corn which mature at varying lengths of time is wonderful, but doubtless even further improvement will be made. Many of us have seen a crop of corn mature, and then the seed of the matured corn planted, and another crop matured in one season. The growing of an early-maturing crop of corn and of a crop of cowpeas in the corn is a common practice in many sections.

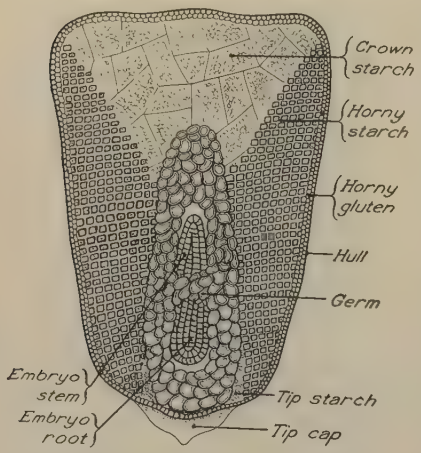


Fig. 53. — High-protein corn kernel
Compare with Fig. 52.

A recent Yearbook of Agriculture makes the following statement, "The efforts to develop improved varieties of corn which have been under way for 20 years or more have increased production by one fourth." That is, one fourth of the corn crop of 1921, or 770,093,000 bushels, was attributable to improved seeds. This quantity of corn at 50 cents a bushel alone would have a value of $385,047,000, almost half the money expended for education in the United States in 1921. Increased yields secured by the use of better and more prolific varieties is clear gain.

Improvement of oats. — In Chapter XVI are recorded the results of numerous experiments of the Experiment Stations of the different states, showing what varieties are best adapted

to the conditions of each state. These are very important data and may be referred to at this time.

The end in view in growing oats is to get the highest yield of the best grade of grain at the lowest cost of production. Aside from cultural methods there are three things to consider which are especially applicable to the topic in hand. These three factors in increasing yields are: (1) developing of prolific varieties; (2) selection of rust-resistant varieties; and (3) developing of oats with stiff stems that will not lodge (Fig. 51).

Prolific varieties have already been developed. The varieties already secured must be held and further improvement must be made. In Wisconsin the Swedish Select yielded ten bushels more per acre than other varieties. At the Ontario Station, Canada, the Siberian was the best yielder of a hundred different varieties. The Kherson and Sixty Day oats are especially superior yielders during short seasons and excel in prolificacy for many states and sections. Zavits states that oats easily can be increased in yield 15 per cent by breeding. This added to our yield in 1923 of 1,302,000,000 bushels would have meant an increase of 195,300,000 bushels. This quantity of oats at the price then prevailing, 40 cents per bushel, would have added $78,120,000 to the income of the farmer.

The black stem rust in oats is like the same variety of rust in wheat and should be handled in the same manner; namely, by eradicating the barberry and by getting early-maturing and rust-resistant varieties.

Lodging of oats is frequent and considerable damage is done, which may be overcome by further development of plants that have stiff stems.

Improvement of cotton. — The average yield of lint cotton per acre in the United States from 1911 to 1920 was 178 pounds per year. This low yield is due more to poor culture and depleted

soils than to the failure to use productive varieties. It is said, however, that the Egyptian cotton introduced in 1901 has become the basis of the long-staple cotton industry in the Southwest and it increased the value of cotton $6,000,000 in 1917, $11,000,000 in 1918, and $20,000,000 in 1920.

Cotton wilt is a disease that stops the circulation of the water in cotton plants by plugging them up. This disease remains in

Fig. 54. — A fine field of Dixie Triumph — a wilt-resistant cotton

the soil for many years. Regarding the control of cotton wilt the Yearbook of Agriculture for 1921 says, "Resistant varieties bred by the Department of Agriculture have come into general use, and these varieties constitute an important and an effective remedy for wilt." It is an important achievement in plant improvement to produce varieties that are wilt-resistant. It helps to increase yields without increasing the costs of production (Fig. 54).

Improvement of grapes. — Grapes have been in cultivation for many years, but most of the excellent varieties now grown in

America originated in the United States. These fine varieties of grapes all came from the wild grape. It is strangely wonderful that so many varieties could be secured from the small, sour, wild grape, which may yet be seen growing in many states. The domestic grape has size, a fine flavor, and various colors, and is prolific — all of which shows a wonderful development and evolution from the wild grape. The chemical composition of grapes varies from and is far superior to that of the wild grape. Doubtless further improvement in grapes along the lines of size, flavor, composition, color, prolificacy, and resistance to disease will be made.

Improvement of apples. — The wild crab was the ancestor of our domesticated apples. It was hard and sour, had many seeds, and little edible pulp. It is doubtful whether it could have lived in the wild state had it not possessed these qualities. Pliny, a Roman naturalist and writer (23–79 A.D.) said that apples were so sour that they could turn the edge of a knife.

From the wild crab have been evolved the many splendid varieties of apples we now enjoy. Unlike the wild crab the domestic varieties have a great deal of edible pulp, are soft and mealy when well matured, have few seeds, and possess acid, semi-acid, and sweet flavors. And yet it is likely that we are just now at the stage of development of apples where real evolution and development begins.

Improvement of sugar beets. — Sugar beets are grown for their sugar content. In 1920 and 1921 the United States produced more than 1,000,000 short tons of sugar each year. A short ton is 2000 pounds. In 1922 the production fell below 700,000 short tons. The average sugar content of beets for 1922 was 15.59 per cent of the weight of the beets raised. If by improvement this could be raised to 16.59 per cent the yield would be increased almost 7 per cent. This added to the 1922 crop

would have increased the sugar yield almost 100,000,000 pounds. It is this kind of improvement that is constantly being sought; that such improvement is possible is shown by the fact that an entire field of 20 acres in the state of Washington averaged 22 per cent sugar.

Edison harnessed electricity, Whitney invented the cotton gin, and McCormick gave us the reaper. These are all valuable. But the man who increases the prolificacy and sugar content of the sugar beet makes a contribution which adds to the food of mankind, a greater service than the invention of a machine which harvests the crop.

Improvement of potatoes. — The potato, like corn and tobacco, is of American origin. As late as the Revolutionary War only two

Courtesy of Missouri Experiment Station

Fig. 55. — Comparative yields of a prolific and a nonprolific variety of potatoes

varieties of potatoes were known in England — a white and a red variety. The greatest improvements in potatoes have come within the lifetime of men now living, and the hundreds of varieties now known have come into existence within the last 50 years.

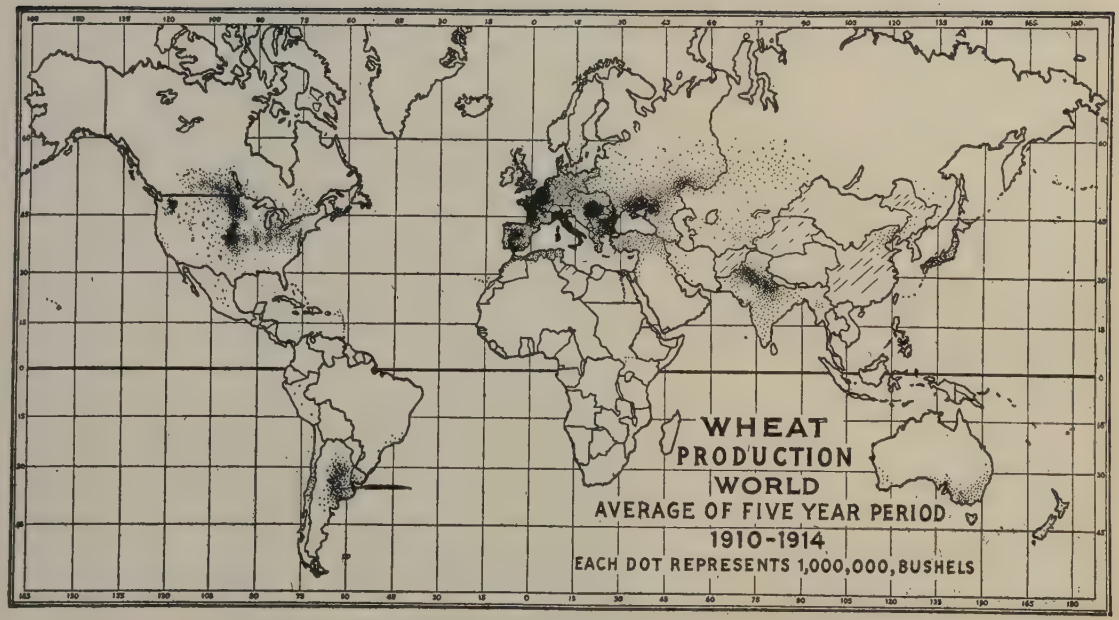
Luther Burbank in 1870, working in his market garden, found a seed ball on an Early Rose potato, saved the seed, and planted it, and from this seed grew tubers of unusual size and of good quality. The Burbank potato was thus originated, and it has added millions of dollars to the income of the potato farmers. Other varieties have been just as valuable. Potatoes are increased in prolificacy by selecting seed from those hills that bear a lot of good, shapely, high-quality potatoes (Fig. 55).

Summary. — The improvement of plants in order to increase production so that production may keep pace with our increasing population is not so important as the improvement of plants in order that farmers may increase their yields and secure as large a yield on 2 acres as they got before on 3 acres. Plant improvement increases efficiency without in any way increasing the cost of production. The 247 domesticated plants have already been greatly improved, but probably the plants which have been improved the most are most susceptible to further improvements. The man who originates or domesticates a new variety or improves an old variety is a real benefactor of mankind.

LABORATORY EXERCISES AND HOME PROJECTS

1. Determine as nearly as possible the amount of flour, meat, milk, butter, and potatoes a person uses in a week's time.

2. Estimate the amount of wheat needed by the population of the United States and compare last year's production with your estimate.



Courtesy of U. S. Department of Agriculture

Fig. 56. — Pre-war world wheat production

The north temperate zone produces most of the world's wheat supply. The United States was second to Russia in production previous to 1914. Now this country ranks first.

CHAPTER XIII

WHEAT

Wheat as a food crop for man. — Wheat is the greatest single food for mankind. It is used more extensively than any other crop; and wherever civilized man appears, wheat follows closely in his train. In fact, the higher civilization mounts, the more demand there is for wheat. It is told upon good authority, however, that half of the people of the world have never seen wheat or tasted wheat products. These people unfortunately are compelled to eat dark bread made from other cereals that are not adapted to bread making. In 1921 the people of Belgium, however, a highly civilized people, used 6 bushels of wheat per person, while the people of France used 8.7 bushels and the people of the United States used 6.3 bushels. Other highly civilized peoples who use much wheat are the English, Germans, Dutch, Russians, Austrians, and the white race wherever found. The use of wheat by the people of the United States is constantly increasing. In 1850 we used less than 4 bushels per person.

Important wheat-producing nations. — Wheat is grown on a larger acreage than any other crop in the world. This is true because it is adapted to a wider range of climatic conditions than any other crop. Wheat thrives best in the temperate zone, but it has been grown within 200 miles of the Arctic Circle and also in the torrid zone. It grows in low and high altitudes and is, in fact,

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: a pint each of hard- and soft-wheat flour; several pint samples of threshed wheat; and a dozen paper (preferable) or porcelain plates.

a very adaptable plant. Wheat is so adaptable and grows under such a wide range of conditions that an entire failure in one section of the world seldom affects the world price of wheat to any great extent.

Wheat and corn are the greatest crops in the world from the standpoint of production. In total bushels produced corn stands

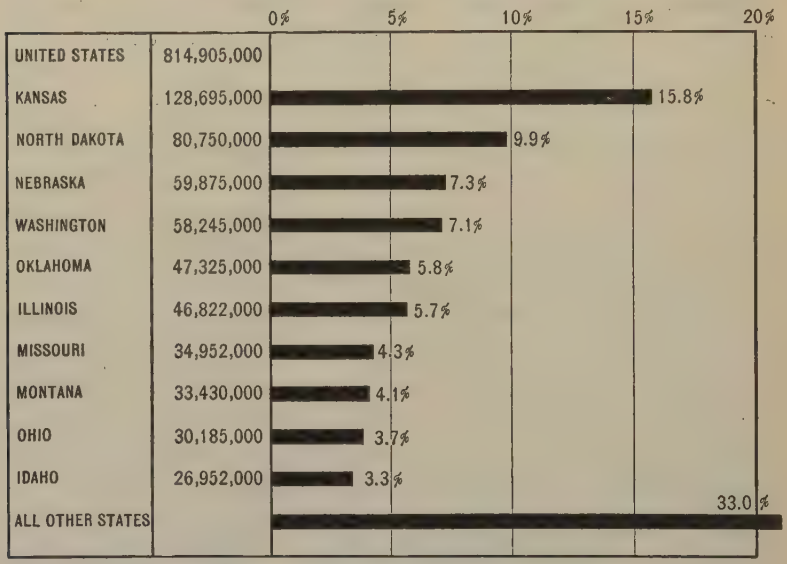


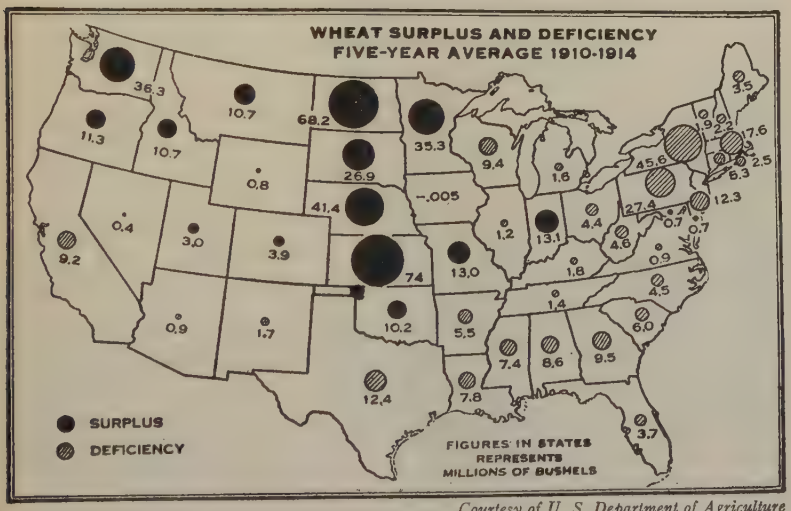
Fig. 57. — Principal wheat-producing states

first, but in pounds produced there is only a negligible difference between the wheat and corn crop. For the ten-year period 1911–1920 the bushels of wheat and corn produced in the world were 3,250,000,000 and 3,750,000,000 respectively.

Although Russia was a strong rival in the production of wheat before the World War, at present the United States stands first. Fig. 56 shows the wheat-producing nations. Russia, India, Argentina, and Canada are competing countries with the United

States in production and exports. These five furnish the world's supply of wheat and largely set the price of this important commodity.

The wheat states. — Since 1914 more than 800,000,000 bushels of wheat are produced in the United States annually. The ten states which were the chief producers of this cereal in the year 1921 are shown with their production in bushels in Fig. 57. These ten states, having only 23 million people, or 21.5 per cent of our population according to the last census, but producing 67 per cent of the total wheat output, easily are the leading exporters of wheat. This is illustrated by the following map.



Courtesy of U. S. Department of Agriculture

Fig. 58. — Wheat surplus and deficiency

States east of the Mississippi with three exceptions do not produce so much wheat as they consume. The same is true of the Southwest.

The Eastern and Southern states with their dense population and the arid Southwestern states import much wheat. Sixty per

cent of the wheat is shipped out of the region where it is grown. Thirty states do not produce enough wheat for their own consumption. Their needs are supplied by the states producing a surplus, and, besides, about 300,000,000 bushels annually is being exported from the United States.

Wheat districts in the United States. — There are six important wheat districts in the United States. Though each district grows a number of varieties of wheat, the kernels of the varieties of a district possess similar characteristics. Hardness, due to the gluten content, color of kernel, and the time of growth are the principal characters which serve as a basis for the wheat districts of the United States. Market quotations are based upon these characters. Each of the six districts and the character of the wheat produced will be briefly discussed:

1. The semihard winter-wheat district includes the states of Missouri, Illinois, Iowa, Indiana, Ohio, Pennsylvania, Kentucky, and the eastern part of Kansas, of Oklahoma, and of Nebraska. The abundance of rainfall produces a wheat high in starch and lower in protein content. It ranges from a soft to a semihard wheat, according to the amount of rainfall in different seasons and sections. Where the rainfall is less, the wheat is harder.

2. The hard winter-wheat district includes most of the states of Kansas, Nebraska, and Montana and overlaps into Missouri, Iowa, Arkansas, and Oklahoma, according to seasonal variations. The kernels of the wheat grown in this district are long, slender, hard, and red in color. A cross section of the kernel is of a grayish-amber color. Hard-wheat flour is excellent for the making of light bread.

3. The hard spring-wheat district includes the upper Mississippi Basin states; namely, Minnesota, North and South Dakota, and parts of Wisconsin, Iowa, Nebraska, Montana, and Colorado. The wheat of this section is spring-sown. It is like the hard

wheats except that the kernels are smaller and harder. It is the best bread-producing wheat grown. About one third of the wheat grown in the United States is grown in this district and large quantities of flour are manufactured here.

4. The soft-wheat district, sometimes called the Pacific Coast or the white-wheat district, includes the states of Washington, Oregon, and California. The wheat has soft, plump, large, white kernels. The flour of this wheat is used for pastries, crackers, and biscuit, because of its large starchy content.

From Duggar's Southern Field Crops

Fig. 59. — Four varieties of wheat

From left to right, Fulcaster, Fultz, Purple Straw, and Currell. These are popular varieties in the Southern States.

5. The Atlantic Coast wheat district includes the states along the Atlantic seaboard. This district produces a soft wheat similar to that produced in California, Oregon, and Washington. This is a relatively unimportant district, except as it supplies the local demands of the district.

6. The Durum wheat district includes parts of the Dakotas, Colorado, Montana, Kansas, and Nebraska. Durum wheat requires less rainfall than any other kind of wheat and is adaptable to the arid and semiarid states.

When other varieties can be grown, they are preferred because their yields are greater (Fig. 59).

History of wheat. — Just when wheat was first grown is not known. However, it may be safely stated that it was grown a long time before history was recorded. The Chinese raised wheat about 3000 B.C. The Egyptians, Hebrews, and the people of Switzerland produced wheat in prehistoric times. Wheat is mentioned in the first book of the Bible, and the early writings of various ancient peoples abound in references to it.

Wheat was not grown in America until after the discovery by Columbus. The first colonists introduced wheat into America, and about 1540 sowed the first seed on American soil. The colonists were largely unsuccessful in their attempts at growing wheat in New England. The Middle Atlantic colonists succeeded better and exported a great deal of wheat and flour in colonial times.

Place of wheat in American agriculture. — Wheat occupies a large place in the agriculture of our people: (1) as a crop requiring time and labor for its production; (2) as a source of income; (3) as an article of commerce; and (4) as our most important food crop.

1. About two million farmers, or one third of those in the United States, grow wheat. In some sections 50 to 60 per cent of the land is devoted to wheat. Although wheat is a machine-produced crop, yet the man and horse labor required to produce the wheat crop is enormous.

2. When wheat yields are fair and prices are reasonably good, the wheat sections prosper; but when prices are low, hard times prevail. The total money income from wheat is exceedingly large, having been $1,400,000,000 on the average for the years 1915–1920; but in spite of this large total income much of the wheat crop is produced at a financial loss to the farmer.

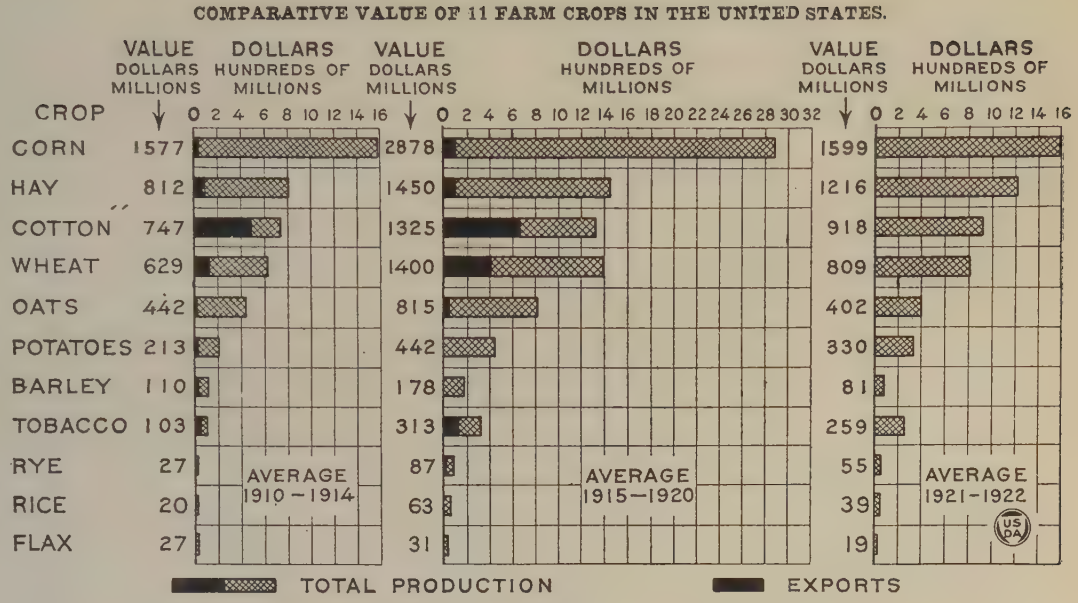

COMPARATIVE VALUE OF 11 FARM CROPS IN THE UNITED STATES.
CROP
VALUE DOLLARS MILLIONS
DOLLARS HUNDREDS OF MILLIONS
VALUE DOLLARS MILLIONS
DOLLARS HUNDREDS OF MILLIONS
VALUE DOLLARS MILLIONS
DOLLARS HUNDREDS OF MILLIONS
0 2 4 6 8 10 12 14 16
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
0 2 4 6 8 10 12 14 16
CORN 1577 2878 1599
HAY 812 1450 1216
COTTON 747 1325 918
WHEAT 629 1400 809
OATS 442 815 402
POTATOES 213 442 330
BARLEY 110 178 81
TOBACCO 103 313 259
RYE 27 87 55
RICE 20 63 39
FLAX 27 31 19
AVERAGE 1910–1914
AVERAGE 1915–1920
AVERAGE 1921–1922
TOTAL PRODUCTION
EXPORTS

Fig. 60

3. Wheat ranks high as a crop. Usually it is fourth in value, being exceeded in value by corn, hay, and cotton. Of course prices change on commodities of the farm more than they do on other commodities; and while the aggregate income may be rather large, yet farmers may not get any net profit. The graph (Fig. 60) gives the comparative value of eleven leading farm crops.

Low yields. — While the acreage yields of wheat are slowly increasing, the increase is comparatively small. According to the United States Yearbooks of Agriculture the average yield of wheat for the ten years from 1890 to 1899 was 13.2 bushels per acre; from 1906 to 1915, 14.9 bushels; and from 1918 to 1922, a five-year period, 13.8 bushels. Some of the foreign countries have much larger yields, and some have smaller ones. The acreage yield of a few countries for the period 1914–1920 will be given:

Highest Acreage Yields of 29 Foreign Countries Reporting (Bushels)		Lowest Acreage Yields of 29 Foreign Countries Reporting (Bushels)	
Denmark	42.5	British India	11.3
The Netherlands	37.5	Australia	10.6
Switzerland	32.3	Argentina	9.8
United Kingdom	31.6	Algeria	9.3
New Zealand	27.3	Uruguay	8.9

While the yields are large in some countries and rather small in others, it is not advisable that we should emulate any of those countries in acreage yields. What is best for our own land, and the same idea may be applied elsewhere, is to produce the largest yield per acre at the lowest cost, or, in other words, efficient production. Aside from the improper preparation of the seed bed, which is one of the greatest handicaps to better yields, the causes

which reduce wheat yields are as follows: (1) lack of moisture, 12 per cent; (2) freezes, 4 per cent; (3) hot winds, 2 per cent; (4) plant diseases, 4 per cent; (5) insect pests, 2.4 per cent, and (6) other causes, about 4.5 per cent. The extent of yearly losses to wheat are about 30 per cent of the possible total yield.

Cost of wheat production. — It is impossible to give the exact cost of producing wheat except under specific conditions. And therefore it will be well for the classes in agriculture through surveys to find the actual cost of wheat production, using the acre and the bushel as the basis for finding the cost. The large items in the cost of producing wheat will be discussed: (1) The value of land, or the rental, is one of the largest items. Land worth $100 per acre with money worth 6 per cent places an overhead charge of $6 on this item. Besides this there are taxes to pay on the land, and this must be counted. (2) The labor on an acre of wheat ranges from $2.50 to $7.50, a fair average being $4 to $5. (3) The cost of machinery ranges from $2 to $4 per acre, depending on the size of fields and the acreage over which the machinery is used. (4) The soil fertility removed by 16⅔ bushels of wheat, or 1000 pounds, is 19.8 pounds of nitrogen, 8.6 pounds of phosphorus, and 5.3 pounds of potassium.

If nitrogen is worth 20 cents a pound, and phosphorus and potassium 7 cents a pound each, then for each one thousand pounds of wheat kernels removed, the land fertility taken out of the soil may be computed thus:

$$\begin{aligned} 19.8 \times .20 &= \$3.96 \\ 8.6 \times .07 &= \quad .60 \\ 5.3 \times .07 &= \quad .37 \\ \text{Total} &= \$4.93 \end{aligned}$$

If all the wheat straw is left on the land and the wheat grains only are removed, it is quite certain that for every thousand pounds of wheat sold off the farm the fertility of the land has

been lowered about $4.93. The cost to produce an acre of wheat therefore varies from $15 to $24.

The following topics may be used in estimating the cost of producing an acre of wheat:

(1) Rental on land
(2) Preparation of soil
  (*a*) Man labor
  (*b*) Horse labor
(3) Seed
(4) Fertilizer
(5) Sowing
(6) Harvesting
(7) Threshing
(8) Cost of machinery
(9) Other items of cost
Total

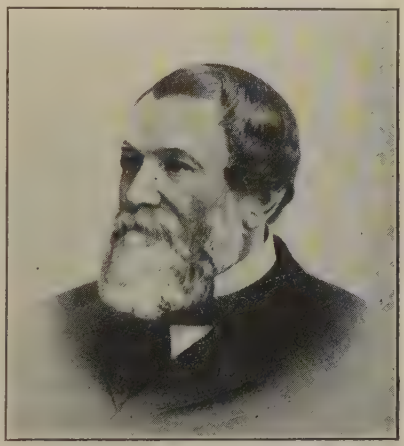
The knowledge of the cost of producing an acre of wheat is important, but a *knowledge of the cost of producing a bushel of wheat is even more important.* High cost per acre does not always mean high cost per bushel. In fact, we may know the cost to produce an acre and yet know nothing about the cost to produce a bushel.

The dominant factor in the cost of producing a bushel of wheat is the *yield per acre.* Of course the costs of producing an acre vary, but they do not vary much on account of the yield. If it costs $15 to produce an acre and the yield is 15 bushels, then it costs $1 to produce a bushel; but if the yield is only 5 bushels, then the cost of producing a bushel is $3. In a survey made by the United States Department of Agriculture it was found that it cost from $1.50 to $19.97 to produce a bushel of wheat under different conditions, the average cost being $1.87 on 284 farms.

Factors aiding in increasing wheat yields. — The main factors which tend not only to increase wheat yields but also to reduce the cost per bushel produced will be discussed in the following paragraphs. These factors are: (1) proper use of machinery; (2) plowing early; (3) rotating crops; (4) drilling wheat; (5) using prolific and adaptable varieties; (6) sowing at the proper time;

(7) using barnyard manures; (8) using commercial fertilizers; (9) combating enemies; and (10) harvesting properly.

1. *Use of machinery.* — Wheat is almost wholly a machine-produced crop. Plowing, harrowing, sowing, harvesting, and threshing are all done by machinery. Just as harvesting machinery has developed from the hand sickle or scythe to a combined reaper and harvester, so all other wheat-producing machinery has gradually evolved. The development has indeed been a wonderful one; for if wheat were produced as of old, threshed by the hand-flail method, and ground with bowl and pestle, it would be impossible to provide our population with flour and bread, and the price of bread would be prohibitive except to the extremely wealthy.



Courtesy of International Harvester Co.

Fig. 61. — Cyrus H. McCormick
Inventor of the reaper, which displaced the scythe and cradle in grain harvesting.

As late as 1850 grass was mowed with the scythe, and grain was cut with the sickle and the cradle and threshed with the flail. The prototype of the modern reaper was invented by Hussey in 1833; and McCormick's reaper was patented in 1834.

2. *Plowing early.* — Early plowing has an important bearing on increasing wheat yields. This is well known by farmers and has been verified by various Experiment Stations, notably those of Kansas, Michigan, Oklahoma, and Missouri.

At the Oklahoma Station time of plowing had the following effect upon wheat yields:

Soil Plowed	Yield per Acre (Bushels)
July 19	31.3
August 15	23.5
September 11	15.3

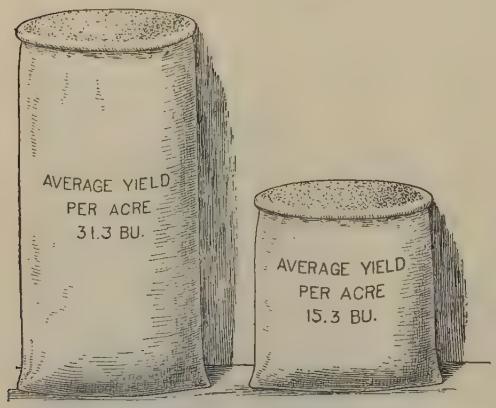


Fig. 62. — Effect of time of plowing on economic wheat production

At left, date of plowing, July 19; at right, date of plowing, September 11.

Land plowed July 19 produced more than twice as much wheat per acre as the land plowed September 11. Early time of plowing alone increases the wheat yield 50 to 100 per cent an acre.

A soil that is prepared early conserves the soil moisture much better than a soil that is prepared late.

3. *Rotating crops.* — Rotating crops bear an important relation to wheat yields. At the Ohio Station the following results were secured:

Relation of Rotation of Crops to Wheat Yields

Treatment	First Decade (Bushels)	Second Decade (Bushels)	Gain or Loss	Twenty Years' Average (Bushels)
Continuous — wheat	9.24	5.79	−37.3%	7.52
Rotation — corn, wheat, and clover	9.92	12.78	+28.8%	11.35

Wheat in the rotation yielded 11.35 bushels, and in the continuous plot it yielded only 7.52 bushels. Wheat yielded 52 per cent more where rotation was practiced than where wheat was grown continuously. In other words, in a similar crop rotation only two thirds as much land needs to be cultivated in order to harvest an equal amount of wheat.

4. *Drilling wheat.* — Drilling wheat helps to increase yields. At the Ohio Station in a five-year test drilled wheat averaged 28.7 bushels, and broadcasted wheat yielded 24.9 bushels. Wheat drilled about an inch deep brings the best returns. Drilling has the following advantages: (1) The seed wheat is evenly distributed in the soil. (2) A uniform stand is secured. (3) Ridges catch and hold winter snows better. (4) Drilled wheat is more uniformly exposed to sunshine. The rate of seeding varies according to the time of seeding, the condition of the seed bed, the size of the kernels, and the method of seeding. From 6 to 8 pecks is recommended as the proper amount to sow (Fig. 4).

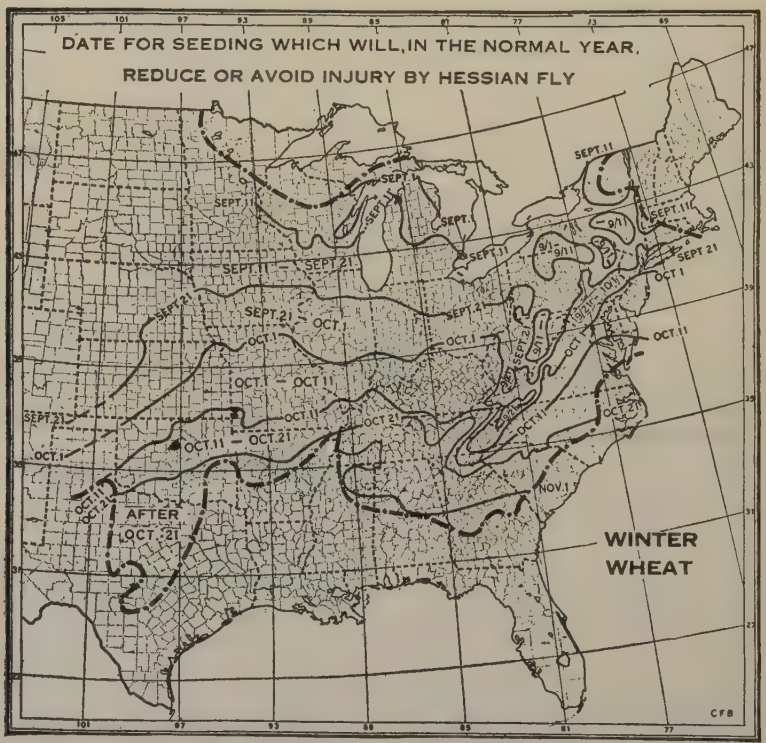
5. *Using prolific and adaptable varieties.* — Plants, like animals, vary greatly in their powers of multiplication. Some increase rapidly, some slowly, and some not at all.

Among the varieties tested at Indiana Station during the last ten years, the six highest yielding and the six lowest yielding varieties of wheat are shown in the following table:

Six Highest and Six Lowest Yielding Varieties of Wheat

Highest Yielders	Bushels per Acre	Lowest Yielders	Bushels per Acre
Purkoff	33.0	Marvelous	21.1
Farmers' Friend	31.8	Big Harvest Fultz	23.3
Michigan Amber	30.0	Burbank's Wonder	26.0
Michikoff	29.2	Red Rock	26.1
Gladden	29.0	Portage	26.5
Early Rudy	28.2	Zimmerman	26.6

6. *Sowing at the proper time.* — No definite date can be set for sowing wheat in different localities, as the time will depend to a great extent upon the season and the condition of the soil. The United States Department of Agriculture recommends that wheat be sown after the fly-free date and furnishes the following map which shows the time winter wheat may be sown:



Courtesy of U. S. Department of Agriculture

Fig. 63. — Fly-free date for seeding winter wheat

In the infested area seeding must be delayed until the adult flies have died or severe injuries may result.

7. *Using barnyard manures.* — The value of barnyard manure to wheat yields is shown in the following data from Bulletin No. 183, Missouri Experiment Station:

VALUE OF BARNYARD MANURE IN WHEAT PRODUCTION

	YIELD PER ACRE 29TH YEAR 1923 (Bushels)
Wheat continuous	0.2
Wheat and manured	10.9
Wheat, corn, oats, and clover	30.0
Wheat, oats, wheat, and clover and manured	39.4

8. *Using commercial fertilizers.* — The College of Agriculture at Columbia, Missouri, for a period of 12 years conducted experiments at 30 different places in the state trying to determine the value of fertilizers in increasing wheat yields. Various seasons and soils were included in these tests, but almost without exception profitable results were secured from the use of phosphate fertilizers. Out of 97 tests only 12 failed to show an increase in the wheat crop where bone meal was used. The average yield including all the 97 tests was 4.5 bushels greater with bone meal than without it. There was also an average increase in the straw yield of 600 pounds per acre. It was the practice to use 150 pounds of steamed bone meal to the acre. Bone meal was worth about $2.10 at usual prices, and $2.50 to $2.65 at abnormal prices. Did 4.5 bushels of wheat and 600 pounds of straw pay for this expenditure?

9. *Combating enemies.* — There are two classes of enemies of wheat, fungi and insects. Of the fungous diseases, there are three that are important; namely, the loose smut, the stinking smut, and the rusts. Loose smut attacks the wheat head and

changes the entire head into a black, powdery mass. It is not very destructive. Stinking smut, according to the United States Department of Agriculture, causes an annual loss of about $11,000,000 to our wheat crop. It attacks the kernels only and

Courtesy of Kansas Agricultural College

Fig. 64. — Effect of fertilizer on wheat

The strip in the center was unfertilized. Compare with the fertilized areas on each side.

is therefore often overlooked; but at threshing time the black, dusty, ill-smelling spores are indicative of its presence. When the kernels are cut, the endosperm, instead of being white, is black and contains the stinking-smut spores. Stinking smut annoys the miller considerably, for one smutty grain blackens a great deal of flour. Stinking smut may be controlled by the use of the formalin treatment for the seed wheat. The treatment is

to spread the seed wheat thinly over a floor; then to a pint of 40 per cent formalin to add 36 gallons of water and with this solution moisten the seed wheat thoroughly. The above amount of formalin will treat about 45 bushels of seed wheat. Oats may be treated in the same way. As soon as the seed is well moistened, it should be covered with a canvas for six to ten

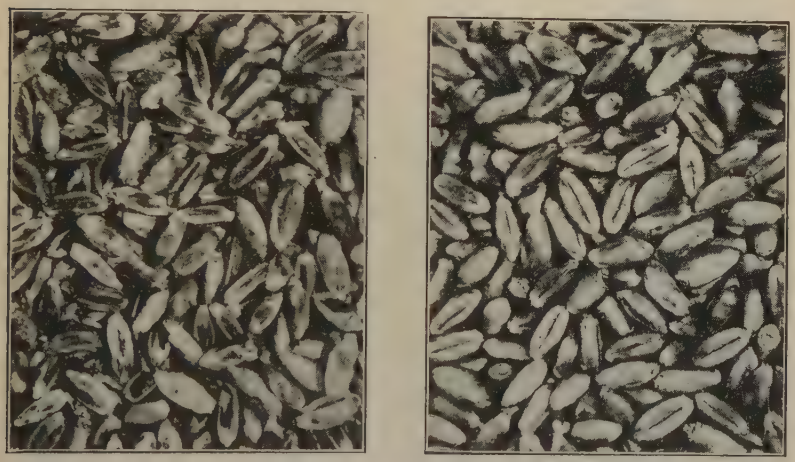


Fig. 65. — Samples of poor and good wheat grains

On left, not fertilized; yield 2.7 bushels; grains shriveled; on right, fertilized; yield 19.4 bushels; plump grains.

hours. This will keep the fumes of formalin around the kernels. Then the seed should be spread out to dry. When dry, it is ready to sow. Good drills will sow the seed when quite damp, but they must be set to sow more seed per acre than if sowing dry seed.

Rusts attack both stem and leaves and do considerable damage in some seasons. There is no effective remedy for the control of rusts, except to grow rust-resisting varieties.

The two chief insect enemies of wheat are the Hessian fly and the chinch bug. The former causes a loss of about 4,000,000 bushels annually. The larva of the Hessian fly looks like a flaxseed, and it is during this stage that the Hessian fly does its damage to the wheat plant. These larvæ live just between the leaf sheath and the wheat stem at the nodes and cause an enlargement. The wheat plant usually breaks down a week or two before maturity. Circular No. 29, Missouri Station, gives the following four points as a basis for control: (1) Destroy the natural home of the fly by plowing early and deep. (2) Keep down all volunteer wheat between plowing time and seeding date. (3) Delay wheat seeding until after the fly-free date. (4) Coöperate with neighbors in practicing these three measures.

Fig. 66. — Adult Hessian fly (much enlarged)

Fig. 67. — Hessian fly larva before flaxseed stage is reached (much enlarged)

The chinch bug is the other important insect enemy of wheat. Chinch bugs hibernate in fence corners, rubbish, and grass. The best way to combat them is to destroy them by burning them in their winter homes during winter or early spring. They may be prevented from going to other fields after the wheat is harvested by plowing a strip of soil around the field 6 to 8 feet wide, mulching the soil thoroughly, and dragging a deep furrow in the plowed strip. Chinch bugs are unable to surmount a pulverized

Fig. 68. — Adult chinch bug (much enlarged)

furrow. The progeny of one female chinch bug under favorable conditions will number 50,000 to 60,000 in one season. An ounce of prevention is worth a pound of cure in combating chinch bugs.

10. *Harvesting wheat at the proper time and taking proper care of it.* — Most authorities agree that wheat may be cut when the

Courtesy of U. S. Department of Agriculture

Fig. 69. — Threshing wheat

straw begins to turn yellow and the kernels are just past the dough stage. The kernels will mature nicely from the nourishment stored in the stems, and the plant and leaves have better food value when cut fairly early. Slightly early cutting often evades lodging of wheat from storms and, of course, prevents shattering (Fig. 51).

The shocking of wheat as soon as it is cut protects the grain and straw from the hot sunshine, gives the kernels a slightly better color, and facilitates the transfer of nutrients in the stem to the kernel. Placing a bundle or two as cap sheaves on the shock protects the grain from sunshine and rain and helps in producing and maintaining the best quality in the grain.

Stacking wheat, after it is sufficiently dry in the shock, also will help to improve the quality of wheat. Stacked wheat will usually sell for 10 to 15 cents per bushel more than wheat that is threshed out of the shock. Wheat that is stacked goes through a sweating process which brightens the kernel and reduces the moisture in the kernel to such an extent that it will usually keep well when stored in bins. It requires from 3 to 5 weeks for wheat to go through the sweating process.

Uses of wheat. — Wheat is used almost exclusively for human food; however, a small amount of wheat and the by-products of the manufacture of flour are fed to domestic animals.

DIGESTIBLE COMPOSITION OF WHEAT AND CORN

	Total Dry Matter in 100 Pounds (Pounds)	Digestible Nutrients in 100 Pounds				Nutritive Ratio	Therms [1]
		Crude Protein (Pounds)	Carbo-hydrates (Pounds)	Fat (Pounds)	Total (Pounds)		
Wheat . .	89.8	9.2	67.5	1.5	80.1	1 : 7.7	82.63
Dent corn .	89.5	7.5	67.8	4.6	85.7	1 : 10.4	88.84

Time spent in thoroughly examining the above table, and in memorizing it, as one would learn the multiplication table, is time well spent. Wheat and corn have practically the same proportion of dry matter; wheat has 9.2 per cent digestible protein

[1] A therm is the amount of heat required to raise 1000 pounds of water nearly 4 degrees Fahrenheit.

and corn has 7.5 per cent; the amount of starch in each is practically identical; but corn yields 4.6 per cent fat as against 1.5 per cent in wheat.

The nutritive ratio[1] of wheat is as 1 : 7.7 and of corn 1 : 10.4, showing that wheat contains more protein in proportion to the carbohydrates and fats than does corn. That is, wheat is more nitrogenous than corn. The heat-producing value of corn is 88 therms, and of wheat 82 therms per hundred pounds.

The entire wheat grain furnishes more food per 100 pounds than any of the wheat products. In the manufacture of flour the covering of the kernel and the germ are removed, two important parts of the kernel, as far as food value is concerned. In fact, the germ and the bran contain more mineral matter and protein material than the white starchy part of the kernel out of which flour is made. The whole is better than a part. Too much money and time are spent on the separation of the wheat kernel.

Wheat flour, wheat, wheat screenings, middlings, bran, and wheat straw have the following digestible composition:

DIGESTIBLE COMPOSITION OF FLOUR, WHEAT, ETC.

	Total Dry Matter (Pounds)	Digestible Nutrients in 100 Pounds				Nutritive Ratio
		Crude Protein (Pounds)	Carbo-Hydrates (Pounds)	Fat (Pounds)	Total (Pounds)	
Wheat flour .	87.7	8.1	69.6	0.9	79.7	1 : 8.8
Wheat . .	89.8	9.2	67.5	1.5	80.1	1 : 7.7
Wheat screenings . .	89.8	9.6	47.3	3.6	65.0	1 : 5.8
Wheat middlings . .	89.6	13.4	46.2	4.3	69.3	1 : 4.2
Bran . . .	89.9	12.5	41.6	3.0	60.9	1 : 3.9
Wheat straw	91.6	0.7	35.1	0.5	36.9	1 : 51.7

[1] See p. 152.

Sixty pounds of wheat may be made into the following products under different conditions and milling processes:

FLOUR, BRAN, AND SHORTS MADE FROM 60 POUNDS OF WHEAT

	FLOUR OF VARIOUS KINDS (Pounds)	BRAN (Pounds)	SHORTS (Pounds)
From 60 pounds wheat .	40	10	10
From 60 pounds wheat .	35 patent flours 7 low-grade flours	10	8
From 60 pounds wheat .	8 high-grade flours 26 medium-grade 10 low-grade	8	8
Government recommends	45 pounds flour	15 pounds shorts and bran	

The Government's recommendation is good because it requires less work and less expense to separate the grain into two or three products than to separate it into five products. In fact, coarse flour, with much of the bran left in it, is more nourishing than the finely milled, very white flour.

Nutritive ratio (abbreviated N. R.). — The nutritive ratio of a single feed or of a ration is the proportion of the digestible protein to the digestible fats multiplied by $2\frac{1}{4}$ plus the digestible carbohydrates. It may be stated in this manner:

$$\text{N. R.} = \frac{\text{fats} \times 2\frac{1}{4} + \text{carbohydrates}}{\text{protein}}.$$

To illustrate, corn has this composition: fats 4.6 per cent, carbohydrates 67.8 per cent, protein 7.5 per cent. Therefore the nutritive ratio is found as follows:

$$\text{N. R. of corn} = \frac{4.6 \times 2\frac{1}{4} + 67.8}{7.5}, \quad \text{or } 1 : 10.4$$

The fats are multiplied by $2\frac{1}{4}$ in order to reduce them to their carbohydrate equivalent. That is, fats will produce $2\frac{1}{4}$ times as much heat energy in the body as will carbohydrates, which are composed of starches and sugars. The N. R. of any feed or ration may be found in the same way. For a fuller treatment of feeding farm animals see Gehrs' "Live Stock and Farm Mechanics," pp. 26 to 37.

Summary. — Wheat is the greatest human-food crop in the world, and from an international standpoint the greatest crop of commerce. In the United States wheat ranks among the upper three or four crops as to its value and second as a crop of commerce.

The great wheat-producing nations are the United States, Russia, India, Argentina, and Canada, and the leading wheat states are Kansas, North Dakota, Nebraska, Washington, Oklahoma, Illinois, Missouri, Montana, Ohio, and Idaho. The rest of the states grow about one third of the wheat crop.

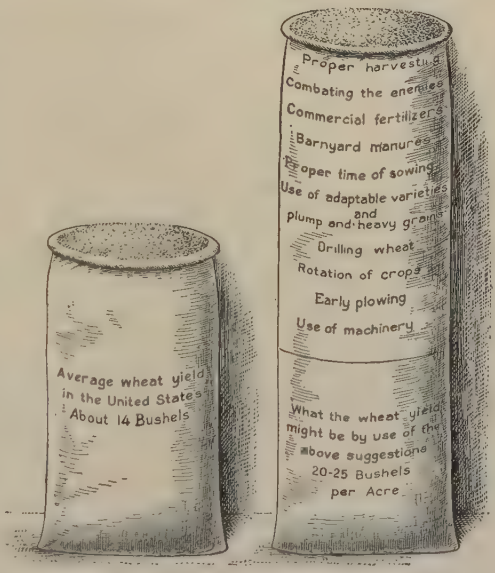

Proper harvesting
Combating the enemies
Commercial fertilizers
Barnyard manure
Proper time of sowing
Use of adaptable varieties and plump and heavy grains
Drilling wheat
Rotation of crops
Early plowing
Use of machinery
Average wheat yield in the United States About 14 Bushels
What the wheat yield might be by use of the above suggestions 20-25 Bushels per Acre

Fig. 70. — Present and possible wheat yields
Culture methods suggested here would greatly increase wheat production.

The acreage yields of the United States are not very high, but the acreage is large, and often there is a slight overproduction,

which results in low prices. The farmer is interested in reasonably high yields per acre, produced efficiently, and a profitable price per bushel.

The factors which will help to produce wheat efficiently are important, for practically each one of the factors is more or less used by every producer of wheat. They are of interest to the farmer because they help him to produce more wheat at less cost, and likewise they are of interest to all consumers of wheat. In fact, it is believed that wheat yields can be almost doubled and the increased production will not increase the present production cost more than one half. Increased acreage production, efficiently produced, a reasonable return to the farmer, and wheat sold at a living price to all are what the consumer wants.

LABORATORY EXERCISES AND HOME PROJECTS

1. Every pupil in the school may help in taking a wheat survey. Secure the following data from every farmer of the district. Have pupils keep data in a notebook and leave a permanent record in the school. Record as follows:

Name of Farmer	Acres in Farm	Acres in Wheat	Per cent of Farm in Wheat	Variety of Wheat

2. Weigh about 50 grams of soft- and of hard-wheat flour. Make each batch into a thick dough by adding water and working. Then wash each until the starch has been washed out. Set away for several days to dry. When dry, weigh the dough. Divide this weight by the original weight. This will be the per cent of gluten. Record the results.

3. Study several varieties of wheat, using the following table:

DESCRIPTION OF GRAINS OF WHEAT. CHECK CHARACTER THUS: ✓

	VARIETY				
	FULTZ				
1. Hardness					
1. Very hard, flinty					
2. Medium					
3. Soft					
4. Very soft, starchy					
2. Appearance of cross section					
1. Very horny					
2. Horny					
3. Starchy					
4. Very starchy					
3. Color					
1. Red					
2. Medium red					
3. White					
4. Plumpness					
1. Plump					
2. Medium plump					
3. Shriveled					
5. Cheeks					
1. Full and plump					
2. Flat and thin					
6. Crease					
1. Very deep					
2. Medium deep					
3. Shallow					
4. Very shallow					

4. Have pupils, with the help of their parents, figure the cost of production of an acre of wheat, using the cost items given in this chapter.

5. Find the cost of each tool and machine used in wheat production. Itemize the charge for each implement used. Find the total charge for each implement used. Find the total charge for all tools used. If tools last ten years, what is the depreciation of each one yearly?

6. From a sample of wheat, sort out fifty good, plump, heavy kernels and fifty poor, shriveled, light kernels. Germinate each by placing between moist blotters placed in a plate. Maintain proper conditions for germination. Record your results.

7. Secure samples of wheat and score according to the following score card:

SCORE CARD—WINTER WHEAT

SCALE OF POINTS	SAMPLE							
	Standard							
1. Uniformity of kernels	10							
2. Color and purity	10							
3. Size and plumpness of kernels	15							
4. Hardness	15							
5. Per cent of foreign matter	15							
6. Soundness	20							
7. Weight per bushel	15							
Total	100							

Explanation of the score card:

1. Uniformity (10). — To secure full score the kernels in the sample should be characteristic of the variety, similar in shape, and practically of the same size.

2. Color and purity (10). — The kernels should be clean and bright in color, characteristic of the variety. If the sample contains kernels different in shade of color from the majority, cut one point for each two per cent of these present.

3. *Size and plumpness of kernels* (15). — The size of the kernels is important both from the farmers' and millers' standpoint. The kernels should be large, plump, and well filled; the crease narrow and deep; the cheeks well rounded. Cut one point for each two per cent of small or shriveled kernels found.

4. *Hardness* (15). — The grains should be hard and horny. Hardness is determined by cutting a number of grains in cross section. If the majority show white and starchy, give a rather low score.

5. *Per cent of foreign matter* (15). — The sample should be free from all weed seed, dirt, and other foreign matter. Cut one point for each weed seed found and according to judgment for other foreign matter.

6. *Soundness* (20). — The sample should be free from all broken, sprouted, smutty, or musty kernels. The bran should not be cracked, blistered, weathered, or streaked. Separate these from the sample and estimate the per cent. Cut one point for each per cent present.

7. *Weight per bushel* (15). — A good wheat sample should weigh 60 pounds per bushel. Deduct two points for each pound below the standard.

8. If a man raises 21 bushels of wheat on an acre, how much nitrogen, phosphorus, and potassium is taken out of the soil? What is the money value of the fertility removed? A bushel of wheat weighs 60 pounds. Figure this problem on the actual number of bushels raised by the farmers of your locality.

9. Write a four-hundred-word paper on "How Wheat Is Grown on the Home Farm (or Elsewhere)."

CHAPTER XIV

MARKETING WHEAT

Marketing a part of production. — Secretary of Agriculture Henry C. Wallace states in the 1921 Yearbook:

"Marketing is as truly a part of production as is the growing of the crop, for the crops have no value unless they can be put into the hands of those who need them. The assembling, storing, and distributing of farm products are productive enterprises, and those engaged in this work require much the same economic and technical information as that required by farmers."

To know what the consumer wants requires a knowledge of the market classes and grades of all kinds of agricultural products. For the farmer blindly to produce things which he can not sell is economic suicide. To market and distribute farm products advantageously is a difficult task; yet it is one which vitally concerns the farm. The farmer should study the marketing of his products, for it is a matter of direct interest both to him and to the consumer.

Production and use of wheat. — The production and consumption of wheat is constantly increasing in the United States. The per capita consumption is increasing, because bread is relatively cheap and is an excellent food, and also because city people use more bread than country people do; and the proportion of city people to our rural population has been and is constantly increasing.

Census Reports show that during the 30 year period from 1850 to 1880 the total production of wheat increased $4\frac{1}{2}$ fold; but

during the 40 year period from 1880 to 1920, the total production of wheat did not quite double.

PER CAPITA CONSUMPTION OF WHEAT FOR DIFFERENT PERIODS

PERIOD	PER CAPITA CONSUMPTION (Bushels)
1839–1849	3.8
1875–1884	4.9
1905–1914	5.6
Present time	6+

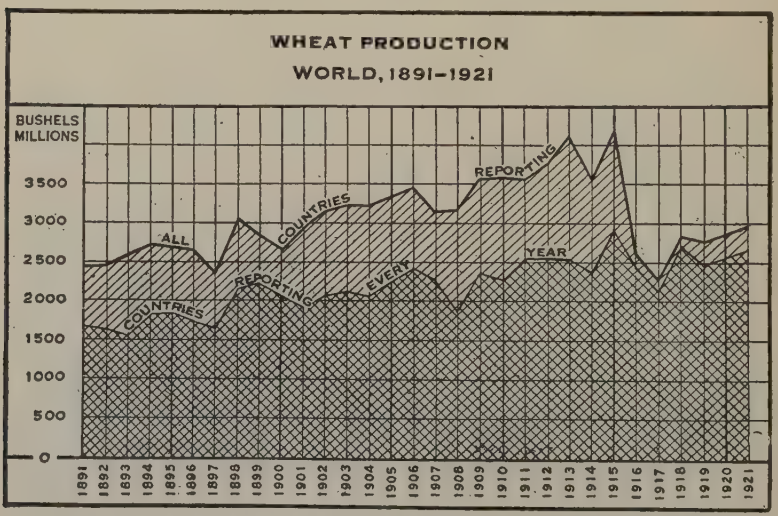
We are exporting about 250,000,000 bushels of wheat yearly. The time is certain to come when we will consume our entire present output of wheat, and we will either have to grow more wheat or import wheat from other countries. Whether we shall grow more wheat or import it will depend upon prices paid the farmer.

Prices of wheat depend upon supply and demand. — Let us say, first, that the price of one commodity may depend to a great extent upon the prices of other commodities. When the prices of commodities in general are low, the price of wheat will be low; when the prices of other commodities are high, the price of wheat will likely be high. That is, prices in general on commodities will rise and fall together. IT MAY BE QUITE TRUE THAT A BUSHEL OF WHEAT AT 50 CENTS WILL BUY MORE THAN A BUSHEL AT SOME OTHER TIME SELLING FOR $1.25. The important point to remember is that the quantity of goods that can be bought for a bushel of wheat is more significant than the number of dollars or cents for which it will sell. The purchasing power of the 94 cents per bushel received by farmers Dec. 1, 1921, was less than that of the 49 cents per bushel received by farmers Dec. 1, 1894.

While the price of other commodities reflects itself in the

price of wheat, there is really another fundamental thing which affects the price, and that is the supply of wheat. The supply depends upon three things: (1) the production for the current year in the United States; (2) the production in other countries; and (3) the quantity in storage.

1. When the total wheat produced in the United States is low, the prices are stronger; but when there is an overproduction, prices are usually below the cost of production. If there are 105,000,000 people in the United States and the per capita consumption plus the seed used is 6 bushels, it is evident that we consume and use for seed 630,000,000 bushels. And since our annual export is about 250,000,000 bushels, then we must produce about 880,000,000 bushels of wheat to feed our people and provide our export trade. But if we were to produce 200,000,000 bushels above our requirements in a single year, and the



Courtesy of U. S. Department of Agriculture

Fig. 71

people of other nations should produce in excess, it is certain that prices would fall to hazardously low levels.

2. The price of wheat is largely determined by the world's wheat production. Fig. 71 shows the production for the 31-year period 1891–1921. Observe that production increased steadily up to 1915. Since the World War satisfactory statistics of production have not been available from some of the large-producing areas.

The wheat production in bushels of some of the leading wheat-producing nations for 1921 was as follows:

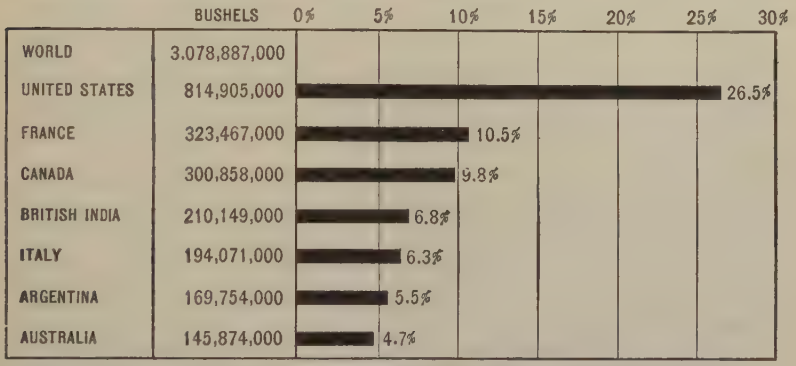


Fig. 72. — Wheat production of leading countries, 1921

The nations which export large quantities of wheat and are really competitors are Russia, India, Canada, and Argentina. The price of land in Russia, Argentina, and India is comparatively low; labor likewise is low; hence these countries compete keenly with the United States in selling wheat. In fact these nations can pay high transportation charges and yet undersell the United States.

3. The quantity of wheat in storage on farms, in country elevators, and in terminal elevators is a factor which affects the supply of wheat. About one third of the wheat is marketed in

July and August; and three fourths of the entire crop is marketed in the six months from July to December. When wheat is high, more is marketed; but when it is low, smaller amounts are sold. Prices on wheat are generally lowest in August and September and highest in June and July. A more even and constant marketing throughout the year would tend to stabilize the price of wheat and on the whole would result in higher prices for the farmer.

Market classes and grades of wheat affect the price. — Of course different types of wheat are grown in different parts of the United States. This is mostly due to a variation of climatic conditions. But regardless of type there are classes, grades, and subgrades of each type. For illustration, the newspapers in their market quotations may name such classes as red winter wheat; hard winter wheat; yellow hard winter wheat; amber durum; and soft white wheat. Each class is divided into grades 1, 2, 3, 4, 5, depending upon the test weight per bushel, moisture content, percentage of damaged kernels, purity, cleanliness, and condition. Any grade of wheat grading below No. 5 is known as "sample grade." The market grade into which a wheat falls because of quality, etc. affects its price.

Freight rates affect the price of wheat. — Farmers get the world price for their wheat minus the freight rates and the risk carried by the purchaser. It is with freight rates we want to deal just for a moment so that the pupils may have some definite information as to how they affect the price of wheat.

The manufacturer prices his article f. o. b. (free on board), and the user of the article pays for the article plus the freight; but the farmer in selling wheat gets a price which is equal to a C. O. D. (cash on delivery) price minus the freight. Let us quote the United States Yearbook of Agriculture:

"The expense or cost of taking wheat from the farm to the market is an important factor in determining the price the farmer

obtains for it. Freight rates make up an important part of the costs of marketing. Before the war it cost from 8 to 10 cents per bushel to ship wheat from Chicago to New York, and about 12 cents from Kansas City to New Orleans. Beginning with 1917 the rates rose, and by 1920 they had doubled. The history of

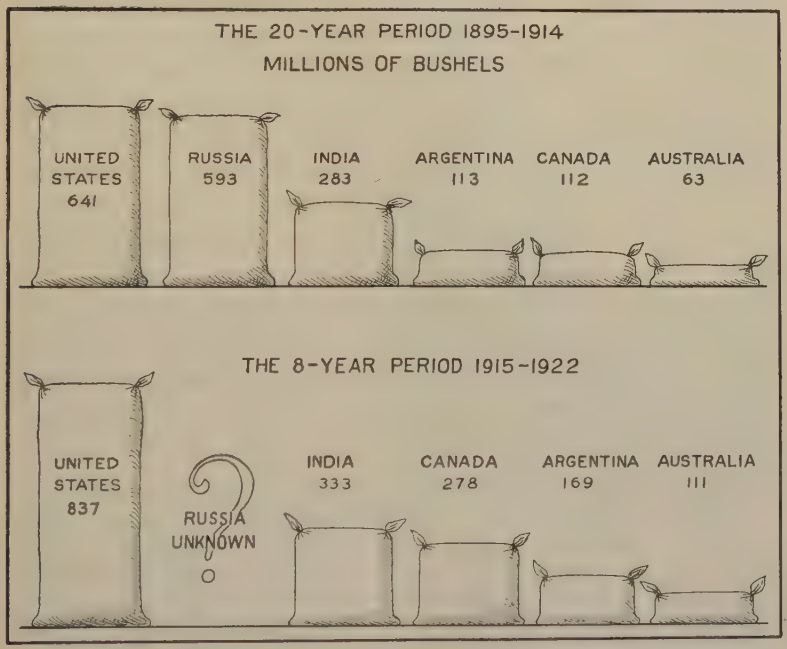


Fig. 73. — Average annual production of wheat in six leading countries

freight rates from Chicago to New York is interesting. Following the Civil War rates were very high. Later they declined from about 32 cents per bushel in 1870–1873 to 8 cents per bushel in 1905.

"The rate for 1920 was the highest since 1886. The high rates scarcely were felt until the price of wheat started downward.

To pay 16 cents out of $2.70 did not seem so burdensome as paying 8 cents out of $1; but when the price of wheat fell to $1.60 in New York, as it did in 1921, the 16-cent rate became a real burden, as most of the surplus wheat is produced west of Chicago."

The world price on wheat is largely influenced by the Liverpool market, and the Liverpool price is dependent upon the production and supply of wheat in the world. The freight rate from New York to Liverpool from 1901 to 1910 was 4 cents per bushel. During 1922 it rose to $9\frac{1}{4}$ cents. The farmer gets the price paid in Liverpool minus the cost of carrying the wheat to Liverpool. This matter of transportation cuts the price of the farmer's crop.

What the farmer should receive is the world price, and some one else should pay the freight; just as some one besides the manufacturer pays the freight on manufactured goods.

Marketing a proportional part of the wheat crop at weekly intervals. — The bulk of the wheat is marketed soon after it is harvested. The following table shows when farm products are marketed according to the Crop Reporter of the United States Department of Agriculture:

When Farmers Sell Their Wheat — Six-year Averages

Month	Per Cent	Month	Per Cent	Month	Per Cent
Jan.	6.1	May	3.9	Sept.	15.5
Feb.	5.3	June	3.7	Oct.	13.8
Mar.	4.0	July	12.4	Nov.	10.0
April	3.6	Aug.	13.5	Dec.	8.2

This table shows that 55 per cent of the wheat crop is sold in the months of July, August, September, and October. Very little wheat is sold during the months of April, May, and June. If wheat is to maintain a fairly uniform price, it must move upon the market at a uniform rate. If $\frac{1}{52}$ of the total wheat crop is

marketed weekly, it is likely that fairly uniform prices will prevail.

If wheat is held any length of time, it is of course evident that the farmer must receive more for it. One of the extension specialists of the Iowa Agricultural College states that wheat selling for 87.4 cents in July would have to sell for 95.6 cents per bushel the following June if the farmer is to break even on holding his wheat. In arriving at the above figures only three items of cost were considered; namely, shrinkage, interest on the investment, and insurance. Other costs, such as losses due to rodents, weevils, mold, and shattering, building charges, and other risks were not counted but, of course, should be counted.

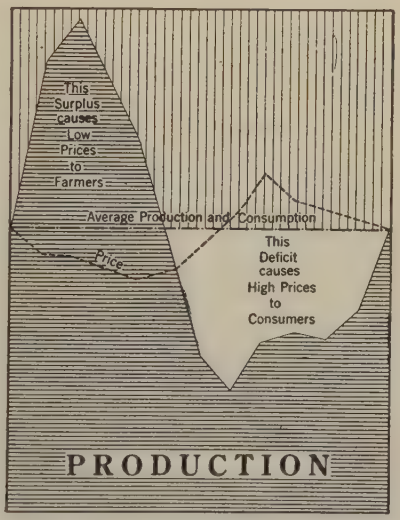

This Surplus causes Low Prices to Farmers
Average Production and Consumption
Price
This Deficit causes High Prices to Consumers
PRODUCTION

Fig. 74. — The problem of farm-product prices

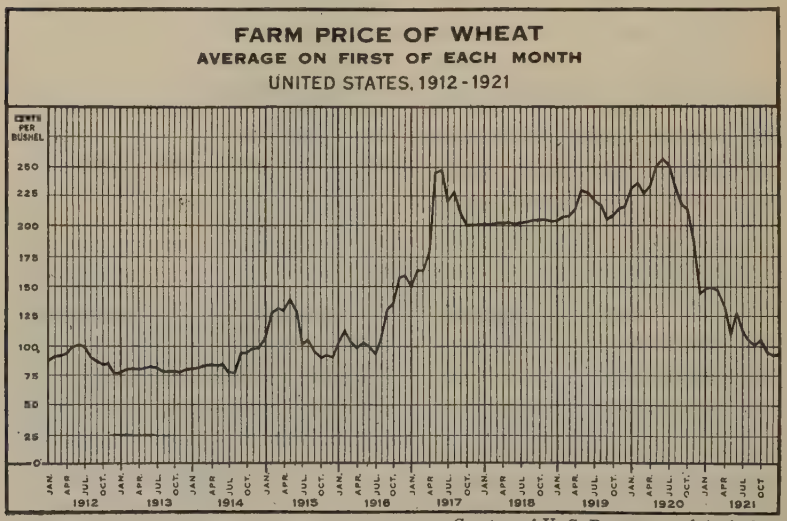
Net prices and not gross prices must be considered. Shrinkage, interest, risk, and cost of storage must all be balanced against advancing prices. The graph (Fig. 75) shows the prices of wheat for the 10-year period 1912–1921. It will be observed that wheat is highest generally in June or July and lowest in August or September.

Two conditions are necessary if the farmer is to market his wheat throughout the year: (1) proper storage and (2) credit.

1. More and better granaries on the farms of the country, more and better elevators, and larger terminal warehouses will

do much toward causing wheat to flow at a more uniform rate to the consumer.

2. Many farmers are compelled because of financial obligations to sell their wheat as soon as harvested. If farmers could get a fairly good price for their wheat for two or three years, they would not need to ask anyone else for credit because they could



Courtesy of U. S. Department of Agriculture

Fig. 75

then carry their own credit. But this is not the case at the present time; hence the importance of the extension of credit to the farmer. By marketing credit is meant the credit needed by the farmer after the grain is harvested so that he can market his wheat in an orderly way. If the price of wheat is high, the farmer will sell his wheat rapidly, and therefore credit will be needed only for a short period. But if the price of wheat is low, the farmer will market his wheat rather slowly, and credit will

be needed for a longer period. Banks organized by farmers and for farmers and extension of state and Federal credit will do much to aid the farmer in getting fair returns for his wheat and so enable him to meet his obligations in a much more satisfactory manner.

Summary. — Marketing of wheat is as important to the farmer as is production. The consumption of wheat is increasing as our population increases. Three things which will help farmers to get better prices are: limiting the production in accordance with consumption, producing a better-quality product, and putting upon the market $\frac{1}{52}$ of the year's crop weekly. Dumping wheat upon the market, selling a poor product, overproduction, and ignorance as to conditions result in the wildest speculation and greatest losses to the farmer. Some aids to orderly marketing are proper facilities for storage of wheat, financial resources to permit the farmer to hold wheat and market it during winter and spring months, and marketing as nearly as possible $\frac{1}{52}$ of the crop weekly. This will result in the stabilization of prices and best results to the farmer and the consumer.

LABORATORY EXERCISES AND HOME PROJECTS

1. Clip from the daily papers market quotations showing classes and grades of wheat and the prices of each grade. Discuss the information found in these clippings.

2. Get the prices of different kinds of flour and find out the reason for the variation of these prices.

3. If there are any coöperative elevators in your community, study the organizations governing the elevators and find out how they manage their sales in order to make a profit or to prevent further losses.

4. Discuss the following topics: (1) relation of roads in your community to marketing any day in the year; (2) the farmer's chances for making money by holding his wheat; (3) the wheat situation as to needs from a world-production standpoint for this year.

CHAPTER XV

CORN

The most important animal feed produced. — Corn is the "King of Crops." In fact, there are as many pounds of corn grown in the United States as there are of all other cereal crops combined. This is brought out by the following data, which unquestionably entitle corn to the above name.

YIELD OF CROPS IN THE UNITED STATES, 1922

CROP	YIELD PER ACRE	ACREAGE	YIELD IN BUSHELS
Corn	28.1	102,428,000	2,890,712,000
Oats	29.9	40,693,000	1,215,496,000
Wheat	14.0	61,230,000	856,211,000
Potatoes	104.2	4,331,000	451,185,000
Barley	25.2	7,390,000	186,118,000
Rye	15.4	6,210,000	95,497,000
Rice	39.8	1,055,000	41,965,000

The total bushels of corn produced was 2,890,712,000 and of the six other crops, 2,846,472,000 bushels. Not only does the number of bushels of corn exceed that of all the others combined, even including potatoes with the grains, but it is heavier than some of the other grains, such as oats.

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: stalks of dent, pop, and sweet corn; several ten-ear samples of the leading varieties of dent corn; a corn tree; a seed-testing box filled with sand; a few yards of white muslin for making rag-doll tests; a bucket; and a pair of trip balances weighing to grams.

The United States Yearbook of Agriculture makes the following statement about corn: "The value of the corn crop to the American farmer is greater than the value of any other crop grown in this country. In 9 years out of 12, the value of corn has been greater than the combined values of wheat and cotton. In 8 of these years the value of corn has been greater than the combined values of all cattle and swine produced for slaughter."

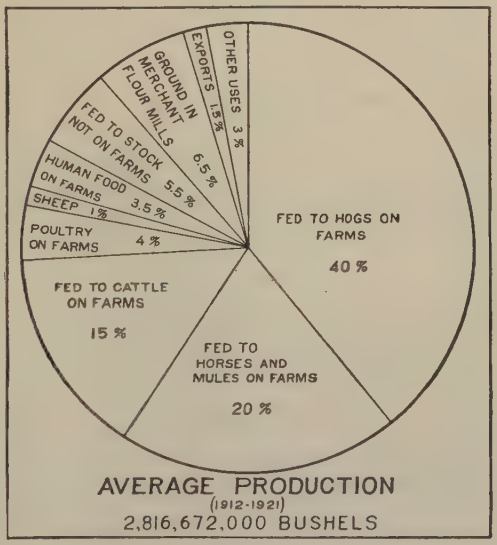


Fig. 76

The hog is the largest consumer of corn, about 40 per cent of the total crop being fed to hogs. Horses and mules use about 20 per cent of the crop; cattle, 15 per cent; and man, about 10 per cent. Corn either directly or by way of animal products is a large source of food for the American people.

Fig. 76 brings out in a striking way the uses made of corn. The corn belt, the hog belt, the cattle belt, and even the horse belt, all are closely interrelated. Dotted maps of these belts would all be very much alike.

"The six states, Iowa, Illinois, Nebraska, Missouri, Indiana, and Ohio, producing 48 per cent of the corn in 1921, had within their borders about 45 per cent of the swine of the country and

over 25 per cent of the cattle other than milch cows on January 1, 1922. In addition these States produced 32 per cent of the chickens and 35 per cent of the hen's eggs produced in the United States in 1919." [1]

World crop of corn. — The United States produces a little more than 75 per cent of all the corn produced in the world. In 1921 the world crop of corn was 4,016,226,000 bushels; and the

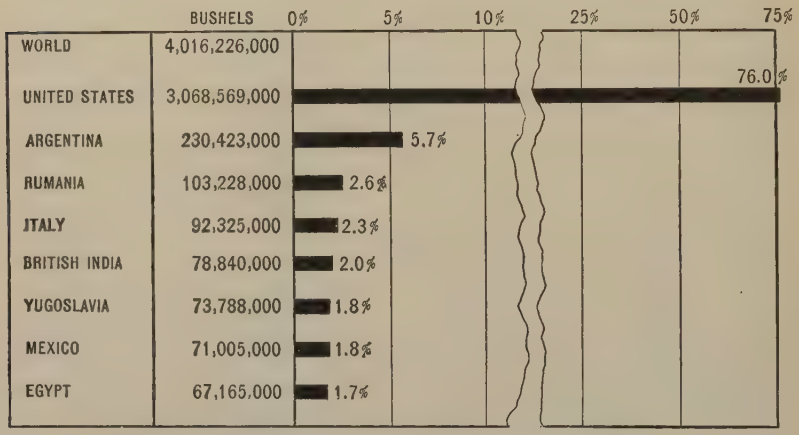


Fig. 77. — Corn production in leading countries, 1921

corn crop of the United States for the same year was 3,068,569,000 bushels. The United States produces such a large part of the world crop that the production in other countries, even with extremely large yields, does not appreciably affect the price of corn.

When we have low yields, the world crop is short; and when our yields are high, the world production is high. The price of corn and of the products derived from corn, especially pork, is largely governed by the status of corn in the United States.

[1] United States Yearbook, 1921, p. 165.

While Argentina and Mexico produce some corn and while Mexico exports a good part of her crop, if the entire crop of these two Western countries were imported into the United States, it would not add very much to the corn produced in this country.

The Corn Belt. — Every state produces some corn; and while the New England States have large yields per acre, they do not produce much corn in the aggregate. The average acreage yield of Maine for the 5-year period 1918–1922 was 47.2 bushels,

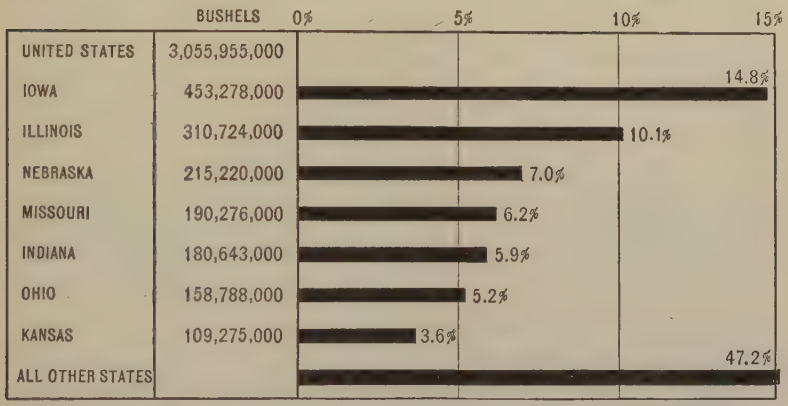


Fig. 78. — Average corn production for the three years 1920–1922

and for all the New England States the average yield was over 45 bushels; while the average for the entire United States was only 28.4 bushels.

The Corn Belt comprises the states of Iowa, Illinois, Nebraska, Missouri, Indiana, Ohio, and Kansas. In 1921 Iowa, the first state in corn, produced 430,500,000 bushels, and the whole of Argentina produced only 230,423,000 bushels, a little more than half as much as Iowa. Iowa, in fact, produced as much corn as the three greatest foreign corn-producing nations: Argentina, Rumania, and Italy.

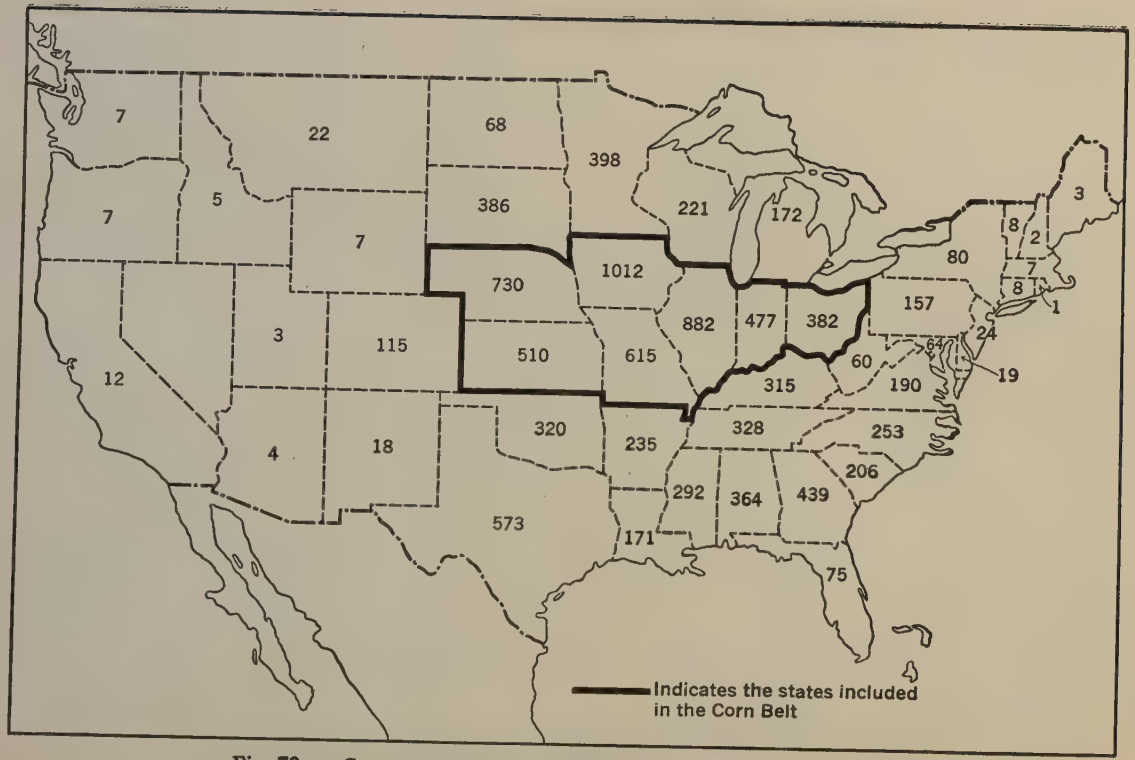


Fig. 79. — Corn acreage, 1921 (each unit represents 10,000 acres)

The Corn Belt can be inscribed in a circle whose center is about the center of Missouri and whose radius extends from this center to the western border of Kansas.

Minnesota, Texas, and South Dakota also produce much corn. For the same years that are indicated in Fig. 78, these three states averaged 137,076,000, 138,054,000, and 115,057,000 bushels respectively.

Fig. 79 gives a fair idea as to the distribution of the corn acreage.

History of corn. — Corn is a native of America. It is believed upon good authority that the Indians of Old Mexico and Central America have raised and used corn for about two thousand years.

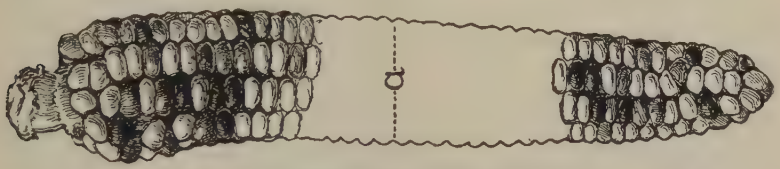


Fig. 80. — A far advanced stage of improvement
A section through the ear at *a* is shown below at the right.

Columbus wrote a letter to Ferdinand and Isabella in 1498, saying, "During my journey in the interior I found a dense population entirely agricultural, and at one place passed through eighteen miles of corn fields." Columbus introduced corn into Spain, and from there it was distributed in turn to France, Italy, Switzerland, Hungary, and Austria. From these countries it was scattered over the entire world.

Types of corn. — There are six types of corn: dent corn, flint corn, pop corn, sweet corn, soft corn, and pod corn.

Dent corn gets its name from the dent at the crown of the kernels. This indentation is caused by the shrinking of the

crown starch in drying during the maturing process. Dent corn, of which there are more than one hundred varieties, constitutes more than 90 per cent of all the corn raised and is the basis of consideration in this chapter. The other types are relatively unimportant and therefore will not be discussed.

Fig. 81. — Ear of dent corn

Years of selection and breeding intervened between this ear and the one shown in Fig. 49.

The corn plant. — The corn plant belongs to the family of plants known as grasses. These plants are characterized by having fibrous roots, jointed stalks, parallel-veined leaves and monocotyledonous seeds. That is, the seeds can not be split into two parts like those of the legume family. The legumes are known as dicotyledonous plants.

Courtesy of U. S. Department of Agriculture

Fig. 82. — Result of lack of fertilization, or pollination

This plant grew alone.

The corn plant has two sets of flowers: the tassel at the top of the stalk and the silks on the ear. The tassels produce pollen grains, which fall upon the silks, and throw out a pollen tube into the hollow silk. When the pollen tube has grown to the place where the kernel is to be formed, fertilization is said to have taken place, and the kernel begins to grow. Very dry or very wet weather may hinder fertilization. Because the tassel matures its

pollen several days before the silks appear, corn has to depend largely upon surrounding plants for fertilization. For this reason a stalk growing alone seldom has much corn on it (Fig. 82).

From fifteen to twenty million pollen grains may be borne on one corn plant. These may be carried by the wind or by insects a quarter of a mile or more. Thus it happens that we sometimes see yellow kernels on white ears of corn, or white kernels on yellow ears. This is caused by cross-fertilization.

Place of corn in American agriculture. — There are three reasons why corn holds an important place among our crops: (1) It will grow in many different soils, conditions, and climates. It grows in the warm, long summers of Central America and Mexico and also in the short summers of the Northern states and Canada. The time required for ripening varies, according to the type of corn, from eighty days in the North to two hundred days in the South. (2) Corn produces more food on an acre than any other cereal crop. So it is grown in almost half the acreage devoted to cultivated cereal crops. (3) Corn holds an important place in our agriculture because it fits into our systems of crop rotations and is easily grown. In regions where only one crop is grown — for instance, wheat in the North, cotton in the South — corn has found a place and is rapidly becoming more popular, because, being a cultivated crop, it helps to eradicate weeds and insects.

Average Yield and Total Digestible Food per Acre, 1918–1921, Inclusive

	Average Yield (Bushels)	Average Yield (Pounds)	Digestible Food (Pounds)
Corn	26.2	1467	1256
Wheat	13.8	828	663
Oats	32.1	1027	723

It will be observed that corn produces more pounds of digestible food per acre than does wheat or oats.

Cost of producing corn. — The cost of producing corn varies from farm to farm and from state to state. In a survey made by the United States Department of Agriculture in the Corn Belt, it was found that on 253 farms it cost $11.90 per acre for the use of the land. This item of land cost is almost as large as all other items combined. It requires reasonably good soil to produce a fair yield of corn.

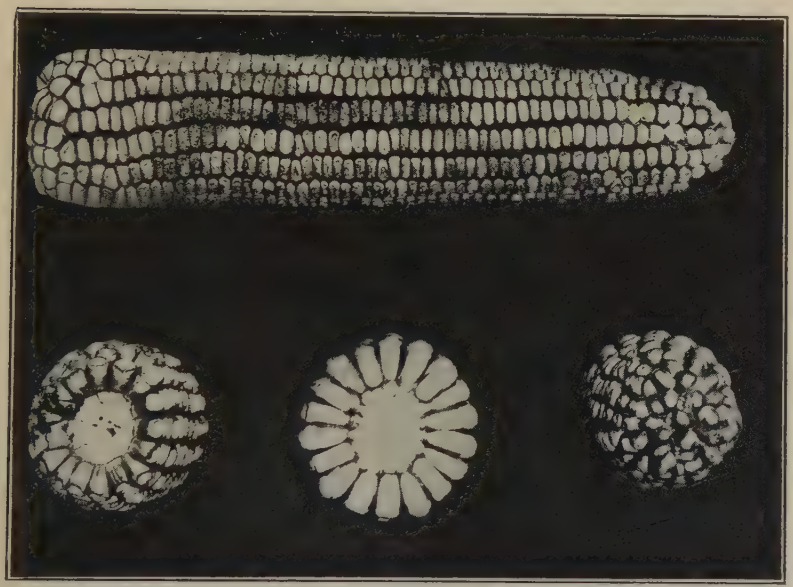
Practically the same items used in estimating the cost of producing an acre of wheat may be used in estimating the cost of producing an acre of corn (p. 140).

More important than acreage cost is the cost to produce a bushel of corn. One of the large factors that affects this is the total yield on the acre. More efficiency in production and lessening the cost of producing a bushel are vital to producer and consumer alike. To produce larger yields in the aggregate is not what is wanted; but larger yields per acre are highly desirable, and this higher acreage yield should be produced efficiently.

The ear. — The size of an ear of corn depends upon the length of seasons. Where the season is long, the ear will be longer and larger than where the seasons are short. In the Corn Belt a good ear isfrom 9 to $10\frac{1}{2}$ inches long, $7\frac{1}{4}$ to $7\frac{1}{2}$ inches in circumference, and weighs about 8 ounces. It is cylindrical and tapers but little from butt to tip. The butt should be cup-shaped and almost covered with uniform kernels of corn. Such an ear will shell a high percentage of corn.

The kernels should be free from mixture with corn of other colors. In white corn a foreign mixture discolors the sides; in yellow corn it discolors the crown. A mixture of varieties of the same colors is difficult to detect, but this should also be avoided

unless a new variety is wanted. The cob should show the color characteristic of the variety. In all white varieties except St. Charles White, which has a red cob, the cob generally is white; in all yellow varieties the cob is red.



Courtesy of International Harvester Co.

Fig. 83. — A well-shaped ear

This ear has a well-filled tip and butt; it should be criticised because the cob is rather small, the kernels are narrow, and the space between the kernels is too great. Compare with Fig. 85.

An ear of corn should be well matured and in good market condition. An ear that is poorly covered at the tip and that has loose grains is immature. Ears that are worm-eaten, decayed, or discolored are in poor market condition. The man who buys corn for feed or uses it for seed must heed the points on maturity and market condition.

The kernels of an ear of corn should be wedge-shaped and should fit closely together in the rows both at the crown and the tip; a good kernel is about one and one-half times as long as it is wide. They should be uniform in size, shape, and composition and should be of a bright, healthy color, full, smooth, and oily.

Courtesy of International Harvester Co.

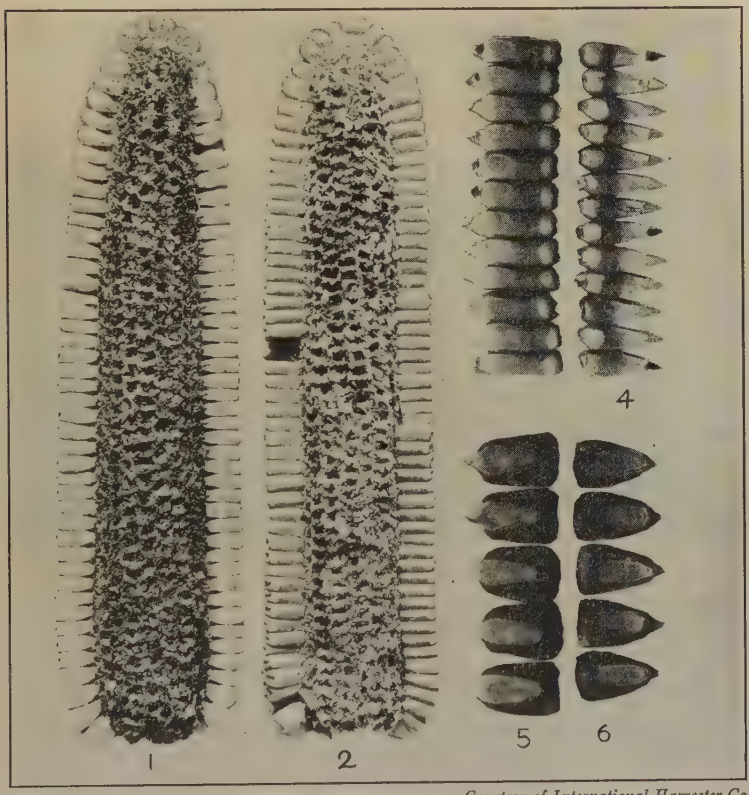
Fig. 84. — Cross sections of three ears

The ear at the top is poor — the cob being small and the kernels too far apart; the left-hand ear has too large a cob and too shallow kernels; the right-hand ear shows right proportion of corn to cob and uniform kernels, well fitted together and of good depth.

The germs should be large, for kernels with small germs have a low feeding value for animals and do not produce good plants.

The cob should be of medium size, about twice as thick as the kernels are deep. Too large a cob gives a small amount of shelled corn, and too small a cob produces a small yield per acre.

Ten-ear samples of corn. — In exhibiting corn it is customary to show samples of ten ears. Each ear should have the



Courtesy of International Harvester Co.

Fig. 85. — Shape of kernels and space between

Ears 1 and 2 are nearly the same size and shape but No. 2 shelled out 33 per cent more corn than No. 1. Rows 3 and 5 are from ear 2 and rows 4 and 6 are from ear 1.

characteristics of the ear described in the last paragraph. The ears should be uniform in length, shape, circumference, color of kernel and cob, indentation, and kind of kernel.

If the ears are alike and all good, it shows that they have been obtained from several years of growth of the same strain and that they represent improved corn.

In judging a ten-ear sample, two kernels should be taken from each ear and laid with germs up in front of the ear. They should be uniform in germs, shape of kernels, and color.

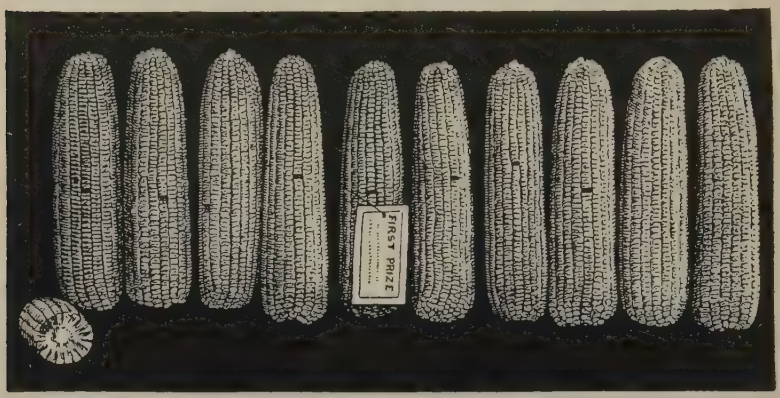


Fig. 86. — Ten-ear sample of corn

This is a good sample of market, exhibit, or seed corn. These ears show corn improvement.

Factors increasing yields. — The use of one or more or, in some cases, all of the following factors will help in increasing corn yields. When and how to use these factors will depend to some extent upon local conditions. It may be that this economic principle could be applied: Use each factor at any time and to the extent to which it will bring economic returns.

There may be other factors that will help to increase yields and decrease the cost per bushel produced but the main factors are: (1) proper use of suitable machinery; (2) proper preparation of the seed bed; (3) selection of the right kind of seed; (4) testing

seed corn; (5) use of an adaptable variety; (6) proper cultivation; (7) rotation of crops; (8) use of barnyard manure; (9) proper use of commercial fertilizers; (10) combating the enemies; and (11) harvesting corn properly.

Each of these factors will be briefly discussed. For a fuller discussion the student should make use of the best reference books.

1. *Proper use of suitable machinery.* — According to the Thirteenth Annual Labor Report, 1855, it cost $16.34 to produce 40 bushels to the acre, mostly done by hard labor; and in 1895 it cost $6.62 to produce an equal amount on an equal area. In this illustration only labor is figured in the cost. The value of the land is not here considered as an item of cost. The time required in 1855 to produce an acre of corn by hand was $38\frac{3}{4}$ hours, and in 1895 it was only 15 hours. In other words, the employment of machinery in corn production reduced the time about one half. Of course the cost was probably not reduced that much when all items of cost are considered. The use of plows, harrows, cultivators, corn binders, and other implements increases the efficiency of corn production. (See Figs. 87, 88, 96.)

2. *Proper preparation of the seed bed.* — This is of prime importance in securing large yields. The points to consider in the preparation of the seed bed are: (1) distribution of labor; (2) catching and holding water; (3) making plant foods available; and (4) providing a deep, loose, but firm seed bed.

Generally speaking, it is more convenient, as far as labor is concerned, to plow corn land in the fall; and where soils are in good condition this is probably the best practice. It is inadvisable, however, to plow rolling land and clay soils in the fall. As far as yields are concerned the Experiment Stations have little, and rather inconclusive, evidence to offer, but practically all agree that fall plowing aids in the distribution of labor.

Fall plowing has the following advantages: (1) The soil is exposed to freezing, which produces a better physical condition of the soil. (2) The organic matter becomes more thoroughly incorporated into the soil. (3) The plant foods become more

Courtesy of International Harvester Co.

Fig. 87. — Corn planter with fertilizer attachment

available. (4) The bacterial organisms are more active in a fall-plowed soil.

Since corn requires a great deal of moisture, 310 units of water to make one unit of dry matter, it behooves the farmer to practice carefully the kind of seed-bed preparation that will catch and

hold a maximum quantity of water, except in some instances where drainage must be employed.

Corn prefers a deep, loose, but firm seed bed. However, the depth of plowing that has proved economically most productive has been a depth of 5 to 8 inches.

Courtesy of International Harvester Co.

Fig. 88. — Corn binder at work

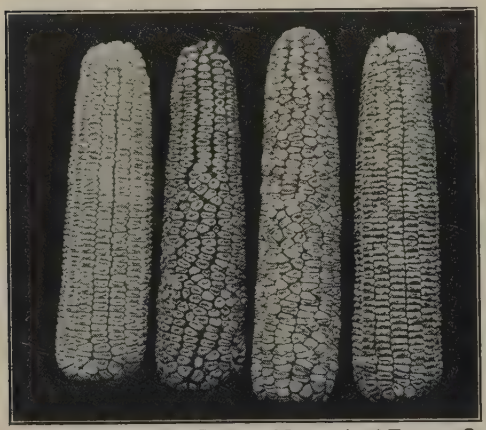
This implement represents a big saving of man labor.

From the table on p. 184 it may be seen that subsoiling and deep plowing can not be economically practiced ordinarily in corn production. Hunt says, in "Cereals in America," "While in a number of trials satisfactory results have been obtained by plowing four inches deep and less, yet the most generally satisfactory depth, all things considered, would seem to be six inches. As compared with wheat and oats, deep cultivation is advisable."

PRODUCTION IN DEEP *versus* ORDINARY PLOWING

	ORDINARY PLOWING 7½ INCHES DEEP (Bushels)	SPAULDING PLOWING AT DEPTH OF 15 INCHES (Bushels)	SUBSOILING PLOWING PLOWED 7½ INCHES, SUBSOILED AN ADDITIONAL DEPTH OF 7½ INCHES (Bushels)
1910	42.13	38.98	42.90
1911	78.49	76.75	79.05
1912	51.08	54.18	47.14
1913	63.20	71.29	74.83
1914	68.55	64.61	71.15
Average	60.69	61.16	63.01

3. *Selection of the right kind of seed.* — There are three methods of seed selection: (1) out of the crib; (2) when corn is gathered; (3) from the field when corn is maturing.



Courtesy of International Harvester Co.

Fig. 89. — Variation in size and shape of kernels

In selecting seed corn one should discard such ears as the two middle ones.

Selecting seed corn out of the crib in the spring is not a good practice, for then the germination power is often lowered and sometimes actually destroyed by early fall freezes which by expansion breaks the germs. The planting of one such frost-bitten ear causes a loss of from eight hundred to nine hundred stalks, or 7 to 8 bushels of corn. If the frost does not entirely

destroy the germ, it will take away much of its strength. Selecting seed corn from the crib has also another disadvantage. We are unable to know upon what kind of stalk the ear grew. The ideal stalk should have a medium height, taper from ground to tassel, and indicate strength.

The second method, that of selecting seed corn when it is gathered, is better than the first, but it too has disadvantages. The desirable ears are thrown at gathering time into a separate box, but there is no way of knowing the time when each matured. The number of days required for corn to mature from the time it came out of the ground up to the time it is gathered should be carefully noted. One variety may vary as much as 15 to 20 days. This is very important in seed selection and can not be ascertained if seed corn is selected at gathering time.

Courtesy of International Harvester Co.

Fig. 90. — Selecting seed corn

The farmer should select seed corn in the field before frost.

By the third method the farmer goes into the field and gathers about twice the amount of seed corn actually needed the following spring. The stalk, the ear, the conditions under which the plant grew, its powers of production, and the maturing qualities of the plant can all be observed. The stalk and ear that mature early and possess the other good points are best. A seed ear from a stalk that has two good ears on it instead of only one should be

selected. An ear grown on a stalk where there are three plants in a hill is better than one grown in a hill of only one stalk. If the plant grew under adverse conditions, and still is equal to other plants grown under more favorable conditions, it is preferable for seed. Poor seed corn means wasted land and wasted labor.

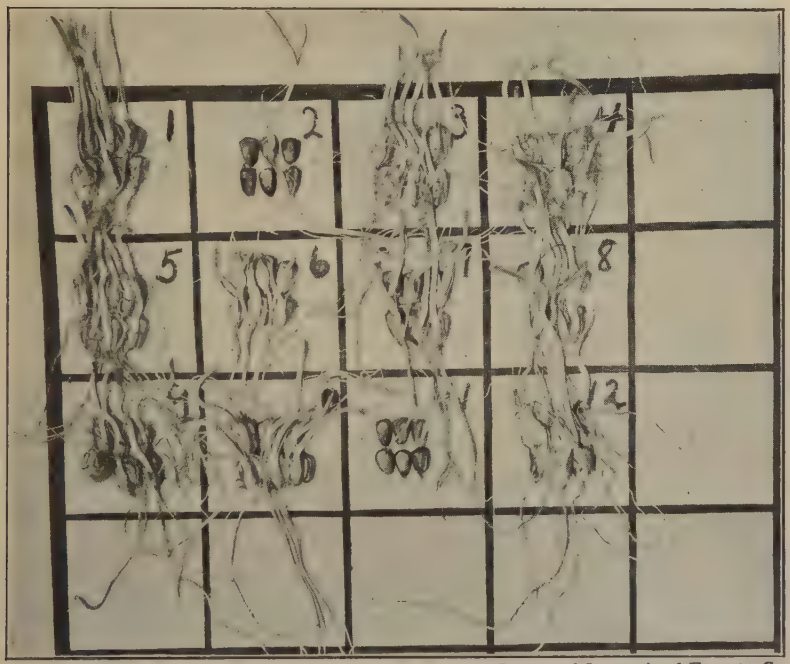
4. *Testing seed corn.* — The average corn yield in the United States is about 28 bushels an acre. If the seed corn is tested, this yield can be increased. The United States Government has demonstrated that, by seed selection alone, the yield of corn in the United States can be increased 20 per cent.

It has been shown also that vigor of germination has a large effect upon yielding power. Tests have shown that corn showing strong germination will yield 80 bushels an acre, medium germination 40 bushels, and weak germination 20 bushels an acre. An ear, therefore, that germinates with little vigor should be thrown out. Annually from one-third to one-half more land is plowed and tilled than would be necessary to get the same yield if perfect stands were secured.

Seed corn should be carefully graded in order that the planter may drop the same number of kernels each time. This helps in getting an even stand. The reason we test and grade seed corn is to lessen waste of land and labor.

The "germination-box" and "rag-doll" methods are usually employed to test seed corn. However, under proper conditions it may be tested in the soil outdoors. The germination box, 20 × 20 inches and 4 or 5 inches deep, is filled with coarse sand or sawdust, over which a white cloth marked into 2-inch squares is laid. The squares may be numbered from one to one hundred. Six kernels taken from different parts of the ear are placed in the squares. The ear is marked according to the number of the square upon which the kernels are laid. A dry cloth is placed over the seeds. Then about one-half to one inch of sand is thrown

over the cloth, and another cloth is placed over the sand. In six to eight days the test is ready, if the conditions for germination have been right. These conditions are: proper temperature (about 70° to 80° Fahrenheit), proper supply of moisture, and



Courtesy of International Harvester Co.

Fig. 91. — Germination test of seed corn

Ears 2, 6, 11 should be discarded and selection made from the other ears according to the vitality of the sprouts.

free oxygen. Unless every kernel germinates, the ear should be discarded.

In the rag-doll test a white muslin cloth is marked into 2-inch squares, and six kernels of corn are laid on each square. The

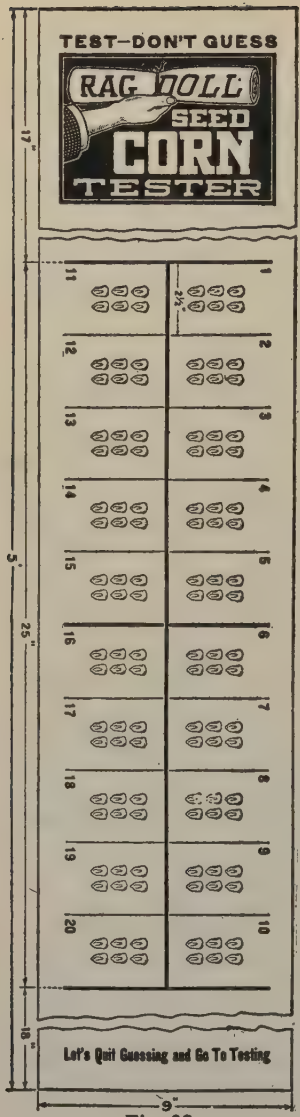



Fig. 92

square and ear from which the kernels are taken are labeled correspondingly. The cloth is rolled up not too tightly and a string is tied around it. The lower end of the rag doll is then set in a bucket containing about two inches of water, and the bucket is kept covered. If conditions are favorable for germination, as outlined above, the test will be complete in about eight days.

5. *The use of an adaptable variety* helps to increase yields, even if all other factors of production remain the same. No two states present the same conditions as to type of soil, length of season, and amount of rainfall; and especially is this true in the Corn Belt. It is for these reasons that each state, and also each locality, must develop or improve varieties of corn suited to its particular conditions. The chief agronomist of the State Experiment Station might even recommend several varieties of corn for one state.

It is advisable, therefore, to consult your own station as to what variety to use, explaining when the request is made whether your soil is upland or lowland and in what section of the state you reside. Then rational advice can be given.

Bulletin No. 181 of the Missouri Station gives the following data on the yields of different varieties of corn:

YIELDS OF CORN VARIETIES AT WARRENSBURG, JOHNSON COUNTY
(Black Prairie Soils of Northwestern Missouri)

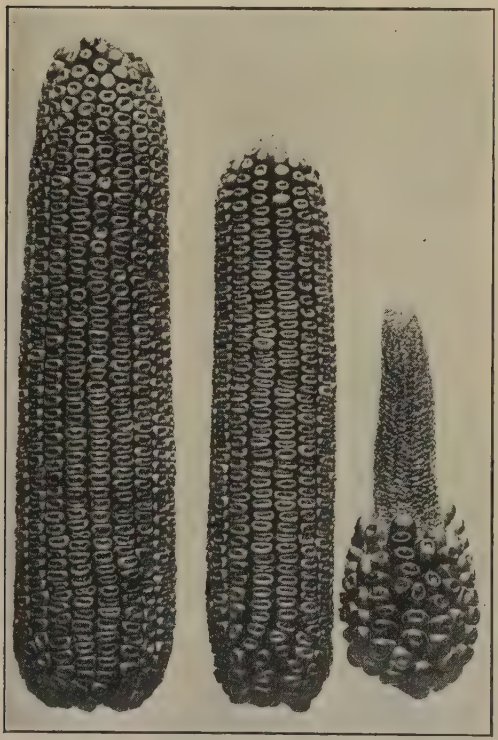
VARIETY	1914	1915	1917	1918	1919	1920	6 Yrs. 1914–15 1917–20
Boone County White	29.6	71.6	45.1	3.4	18.4	34.2	33.7
Commercial White	69.6	86.9	69.3	2.8	27.6	63.6	53.3
St. Charles White	59.1	65.0	58.3	4.9	24.9	38.5	41.8
Leaming	51.3	69.4	47.3	4.4	19.7	25.0	36 2
Reid Yellow Dent	29.3	56.6	42.9	3.9	21.7	....	....
St. Charles Yellow	60 0	64.9	46.2	2.9	....	46.1	....
Johnson County White	50.8	54.6	....	..	....	....	....
Silvermine	52.1	50.1	....	..	....	....	....
Hogue Yellow Dent	46.0	64.9	....	..	....	....	....
Cartner	52.9	66.4	....	..	....	49.1	....
Calico	31.9	44.7	....	..	....	....	....
Funk Ninety Day	47.7	48.1	....	..	....	....	....
Bloody Butcher	33.6	48.4	....	..	29.0	42.8	....
Golden Yellow Dent	42.8	60.6	....	..	....	....	....
Smoot Ninety Day	....	52.7	....	..	....	....	....

This table clearly indicates that some varieties are better adapted to given conditions than others.

Within the same variety strains may be developed that are more prolific.

In Fig. 93 the small ear produced about 200 kernels of a poor grade and at the rate of 7 bushels to the acre, while the large ear produced about 1000 good kernels at the rate of 45 bushels to the acre. The ears grew in the same hill with the same cultivation, plant food, and sunshine. The difference in productivity was simply due to heredity. The farmer should select from the most productive variety those ears that come from stalks that are most prolific.

6. *Proper cultivation.* — This is a powerful factor in helping to increase corn yields. There are two purposes in cultivating corn: The first purpose is to keep out weeds. At the Illinois Station two plots were treated alike in every respect, except one plot was allowed to grow weeds and the other was scraped with a hoe but not cultivated. The plot where weeds were allowed to grow yielded 7.3 bushels, and the one where weeds were kept down by scraping yielded 45.9 bushels.



Courtesy of International Harvester Co.

Fig. 93. — Three ears from the same hill

The difference between these ears is due to the producing power of their parents — a strong argument for seed testing.

Weeds do harm to corn in the following ways: by using the soil moisture; by using plant foods; and by shading the soil and crowding out the sunshine from the corn plant.

The other purpose of cultivating corn is to conserve the soil moisture. It requires an enormous amount of water to mature corn. King of the Wisconsin Station found that 310 pounds of water must pass through the corn plant in order to mature one

pound of dry matter. And at the Nebraska Station it was found that it took 8 inches of rainfall to mature a 50-bushel yield per acre. Most of this rain is required in July and August.

In sixty-one tests at thirteen Experiment Stations with shallow and deep cultivation corn yielded on an average 8.8 bushels more with shallow cultivation. In most cases 1 to 2 inches is considered

Courtesy of International Harvester Co.

Fig. 94. — Right and wrong way to cultivate corn

shallow cultivation and 4 or more inches deep cultivation. The following table contrasts the yields with shallow and deep cultivations:

DEEP *versus* SHALLOW CULTIVATION

	MISSOURI STATION, BULLETIN 14, TWO YEARS	INDIANA STATION, BULLETIN 39, FOUR YEARS	ILLINOIS STATION, BULLETIN 39, FIVE YEARS	OHIO STATION, BULLETIN 282, NINE YEARS
Shallow — Four Cultivations	66.9 bushels	53.5 bushels	70.3 bushels	60.4 bushels
Deep — Four Cultivations	53.5 bushels	50.8 bushels	66.7 bushels	56.4 bushels

A soil mulch helps to conserve soil moisture. If the soil is well prepared, shallow cultivation produces good results provided other factors of production are good. The first cultivation may be deep but never should the roots of the corn plant be cut.

7. *Rotation of crops.* — The rotation of crops does not increase soil fertility, but it does protect soil fertility. Almost every

Experiment Station has data bearing on the relation of crop rotation to corn yields, and all point to the same fact; namely, that crop rotation helps to increase yields. At the Illinois Station a plot on which corn was grown continuously for 28 years produced 22 bushels per acre; but a plot of similar soil, on which corn, oats, and clover were rotated, produced 59 bushels, or more than twice as much per acre. The relation of crop rotation to corn yields is well shown in the following data taken from Bulletin No. 183, Missouri Experiment Station.

Relation of Crop Rotation to Corn Yields

	Yield per Acre 31st Year 1923 (Bushels)
Corn continuous	19.6
Corn and manured	39.1
Corn, oats, wheat, and clover	52.5
Corn, oats, wheat, clover rotation (mowed)	60.1

8. *Use of barnyard manure.* — No one questions that manure increases crop yields, and no better evidence could be given regarding the relation of manure to corn production than to cite a few concrete instances. At the Ohio Station in a 20-year trial corn grown continuously yielded 15.47 bushels; but where 5 tons of manure were applied annually per acre, the yield was 51.81 bushels. The increased yield at 50 cents a bushel caused the manure to be worth $3.65 per ton. (See Fig. 37.)

9. *Proper use of commercial fertilizers.* — At the Ohio Station fertilizers brought the following returns:

Treatment	Quantity Applied (Pounds)	Cost	Average Yield (Bushels)
Unfertilized	none	none	35.5
Stall manure	16,000	....	61.0
Acid phosphate	320	$2.24	67.2
Floats	320	1.60	66.4

The unfertilized plots produced an average of 35.5 bushels; but when acid phosphate was added, the yield was 67.2 bushels. The cost of the fertilizer was $2.24. While corn does not respond so readily to commercial fertilizer as do some other crops, yet in some instances its use brings good returns.

Courtesy of U. S. Department of Agriculture

Fig. 95. — Ear worm devouring corn silks

10. *Combating the enemies of corn.* — The enemies of corn are of two kinds: insect enemies and fungous enemies. The corn-ear worm does the most damage of the insect enemies. Late-maturing corn is attacked more than corn maturing early. Chinch bugs do a great deal of harm to growing corn. Systematic crop rotation is the best means of combating chinch bugs. White grubs and the corn-root aphis do considerable harm in some sections.

Common smut which is a parasitic fungus causes a loss of about 80,000,000 bushels of corn yearly. No practical method of combating corn smut has been discovered, but smut-resisting strains may be developed, which will reduce the losses from this source to a considerable extent.

11. *Harvesting corn properly.* — Many farmers do not husk their corn crop, but let the sheep, cattle, and hogs gather it.

Hogging down corn is a common practice. By this method, little, if any, corn is wasted. Sometimes farmers will fence off small parts of the field by fastening the hog fence wire to the rows of cornstalks. Hogging down corn has the following advantages: (1) It saves the labor and cost of husking. (2) It improves the land, for it leaves all the fertility in the soil. (3) It keeps the hogs healthy and prevents hog cholera.

Animals have more time than man to gather the corn, and like the job better. Why not give them the chance?

Advantages of a silo. — Every farmer who has 10 head of beef or dairy cattle, 25 or 30 sheep, or some mules should have a silo. An average acre of corn will produce from 6 to 8 tons of silage. Corn yielding 30 bushels an acre will make about 6 tons of silage; and corn yielding 60 bushels an acre will make from 11 to 12 tons. By using a silo, nearly all the food of the corn is preserved. If corn is cut up into fodder, from 20 to 30 per cent of the food nutrients are lost. If an acre produces 9 tons of silage, 3 tons of the food value are lost if it is cut up into fodder. For this reason from one-fourth to one-third more stock can be kept on a given acreage when the corn is put into the silo. Corn fodder during the average winter weather is not liked so well by cattle as silage. A cow will eat 40 pounds of silage, and if given fodder she will eat only from 12 to 18 pounds. Silage has some other advantages: (1) It has a beneficial effect upon the digestive tract. (2) It provides a succulent (green) feed in winter time. (3) It tones up the entire system of cattle and sheep. (4) Corn can be put into a silo cheaper than it can be husked and shredded. (5) More feed can be stored in smaller space in the silo than in a haymow or shed.

To the dairyman the silo means succulence of pasture all the year round, cheaper feeding, thriftier animals, and increased production. At the Ohio College it was found that 100 pounds of

whole milk was produced at the rate of 68 cents, when silage was fed, and butter at a cost of 13.1 cents a pound. However, when an average feed was fed without silage, it cost $1.95 to produce 100 pounds of whole milk and 22 cents to produce a pound of butter. Silage and a little cottonseed meal, or clover hay, and

Courtesy of International Harvester Co.

Fig. 96. — Filling the silo

soy beans, or cowpeas, make a well-balanced ration. Moldy silage should not be fed to stock at any time.

The principle of the silo. — Foods and feeds are preserved by canning, drying, salting, pickling, cold storing, and ensiling. Bacteria and molds that cause decay need heat, moisture, air, and food that they may grow. In each of the methods used to preserve food one or more of the things necessary for bacterial growth are absent. In the silo there is no free oxygen. When

the silo is not air-tight, the silage spoils. A thin layer of silage at the top spoils. But a layer of moldy silage protects the rest from the air and preserves it.

TONNAGE CAPACITY OF SILOS FILLED WITH CORN

INSIDE DIAMETER OF SILO	DEPTH OF SILAGE IN FEET					
	20	24	28	32	36	40
(Feet)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)	(Tons)
10	23	30	37	....	....	....
12	33	42	53	64	....	....
14	45	58	72	87	103	120
16	58	76	94	114	135	156
18	74	96	119	144	171	198
20	91	118	147	178	211	244

The depth and diameter of a silo should be such that from $1\frac{1}{2}$ to 2 inches of silage is fed off daily.

Materials used in silo construction. — Silos are made of wood, concrete blocks, brick, cement, glazed tile, and sheet steel. In some states, especially the semiarid and arid states, silos are often made in the ground and are known as pit silos. The pit silo is often lined with a cement wall. The material used in silo construction has no relation to the keeping qualities and feeding value, or palatability, of the ensilage. The kind of silo made depends upon the cheapness of the materials to be used in its construction. The brick and cement silos are more expensive, but of course they last longer than the ordinary wooden-stave silo. Your Experiment Station will furnish literature on silos.

Silage crops. — Corn is the best silage crop. But sorghums, alfalfa, clover, cowpeas, soy beans, and other crops may be used. Silage of corn, soy beans, and cowpeas furnish an excellent ration for dairy cattle, growing cattle, or sheep.

When corn should be put into the silo. — Corn should not be put into the silo when it is green, for it does not contain so much food as it does when it is more mature. The proper time to fill the silo is when the corn shows signs of maturity. Then the husks are turning white, the lower leaves are getting dry, and the

Fig. 97. — Ensilage harvester in operation

kernels are entirely past the milk stage and are dented. If the corn is still more mature and drier, water must be added to it. The amount of water depends upon the dryness of the corn used. A good general rule is: Add enough water to make the moisture content equal to that of green corn. All parts of the corn should be moistened, for the parts that are not well moistened get moldy.

According to the table below it may be observed that there is less water to be handled when the corn is about ripe and that it

contains more dry matter, more protein, more sugar, more starch, and more fat. These are the essential food nutriments, and therefore corn should be put in the silo when it shows signs of ripening.

INCREASE OF DRY MATTER, CRUDE PROTEIN, CRUDE FAT, SUGAR AND STARCH, AND FIBER (YIELD PER ACRE)

	Gross Weight (Pounds)	Water in Crop (Pounds)	Dry Matter (Pounds)	Ash (Pounds)	Crude Protein (Pounds)	Sugar and Starch (Pounds)	Crude Fat (Pounds)	Crude Fiber (Pounds)
Tasseled	18,045	16,426	1619	138.9	239.8	653.9	72.2	514.2
Silked	26,374	22,666	3708	201.3	436.8	2029.2	167.8	872 9
Milk	32,600	27,958	4642	232.6	478.7	2439.8	228.9	1262.0
Glazed	32,195	25,993	6202	302.5	643.9	3239.7	260.0	1755.9
Ripe	28,360	20,542	7818	364.2	677.8	4727.7	314.3	1734.0

Uses of corn. — Corn and grass are the great meat-producing feeds in the United States. No other cereal provides so much feed per 100 pounds at so low a cost as does corn. Pork, beef, and milk production is possible to so large an extent because of the corn crop.

Corn and corn products have the following amounts of digestible ingredients per 100 pounds.

DIGESTIBLE COMPOSITION OF CORN AND CORN PRODUCTS

	Dry Matter (Pounds)	Digestible Nutrients				Nutritive Ratio
		Crude Protein (Pounds)	Carbohydrates (Pounds)	Fat (Pounds)	Total (Pounds)	
Wheat (for comparison)	89.8	9.2	67.5	1.5	80.1	1 : 7.7
Oats (for comparison)	90.8	9.7	52.1	3.8	70.4	1 : 6.3
Corn kernels	89.5	7.5	67.8	4.6	85.7	1 : 10.4
Gluten meal	90.9	30.2	43.9	4.4	84.0	1 : 1.8
Germ-oil meal	91.1	16.5	42.6	10.4	82.5	1 : 4.0
Corn silage	26.3	1.1	15.0	0.7	17.7	1 : 15.1

Corn does not contain quite enough protein to make it a well-balanced ration; therefore, a feed rich enough in protein to balance the ration must be fed with it — clover hay, alfalfa, soy beans, cottonseed meal, tankage, or meat scraps.

A number of Experiment Stations have found that 5 to 6 pounds of corn are required to produce a pound of pork, that 8 to $8\frac{1}{2}$ pounds of corn plus some hay will put on a pound of mutton, and that 10 to 11 pounds of corn plus hay are needed to put on a pound of beef. The amount of feed required to put on a pound of meat depends upon the kind of animal, its age and health, and the weather conditions. If 6 pounds of corn are required to put on a pound of pork, when pork sells at 7 cents a pound and corn at 75 cents a bushel, it can easily be determined whether or not it is profitable to feed swine.

Many by-products are made from corn. The most important products and by-products are starch, corn meal, breakfast foods, oil, hominy, and alcohol. The husks are used for mats and the pith for packing in ships, for when ships are penetrated the pith expands quickly and closes the opening. Paper is also made from the corn plant, and pipes from the cobs.

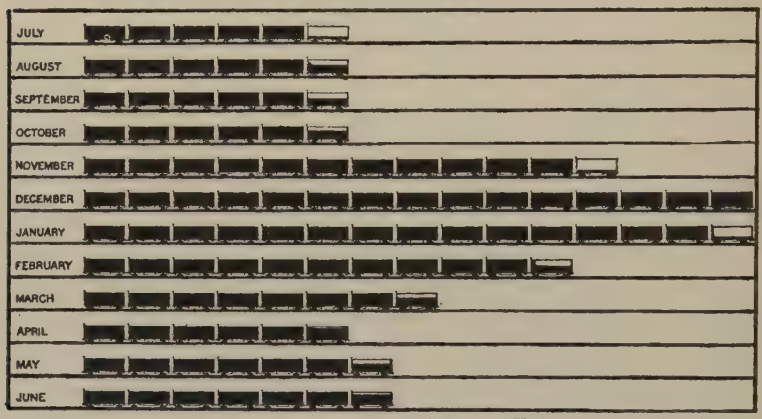
Marketing corn. — In marketing corn it is well to consider the following points: (1) monthly marketing of the crop; (2) quality of the product; (3) moisture content and shrinkage in storage; and (4) surplus and deficiency in different areas.

1. The monthly marketing of the crop varies from year to year, but over 50 per cent of the corn is moved in the four months of November, December, January, and February.

The average amount of corn marketed the last 25 years has been around 500,000,000 bushels. About 15 per cent of the total crop leaves the farm where it was grown. It is an advantage for the farmer to market most of his corn in winter when other work is not so rushing; or it might be better still for the farmer to

market his corn a little more uniformly, say one twelfth of it per month, for this would tend to maintain a more uniform price.

2. The quality of corn marketed bears an important relation to the price received. By *quality* is meant the market class to which it belongs; and this is determined by the size and dryness of grain and its freedom from broken and rotten kernels and from foreign matter.



Courtesy of U. S. Department of Agriculture

Fig. 98. — When the farmer markets his corn crop

Each full car represents one per cent of the total yearly sales.

3. The moisture content of corn varies from 10 to 25 per cent. When corn gets quite dry, it usually still contains about 10 to 12 per cent moisture. In experiments conducted in central Illinois the shrinkage from harvest time to the following August averaged 16.61 per cent. For a ten-year period the price per bushel did not increase sufficiently to compensate for the shrinkage. That is, farmers received more, even if prices were somewhat better later, by selling in November or December generally.

4. Surplus and deficiency in production in different areas affect prices to a considerable extent. About 85 per cent of the corn crop is fed where it is produced. The corn states are also the heaviest producers of hogs, cattle, horses, and poultry.

The acreage devoted to corn seldom varies as much as 10 per cent from year to year in the different states, or in the United States as a whole. If the acreage were reduced 10 per cent and if all the factors of production were bad, then the reduced yield would materially increase the price, and especially would this be true if other crops returned only an average yield. Occasionally, however, farmers plant an increased acreage, and this, with favorable conditions for a bumper crop, so swells the production that the surplus supply ruins the price, and the farmer gets less for his bumper crop than it cost to produce it.

Summary. — Corn, a native of America, is from the standpoint of total food produced and money value the most important crop in the United States. About 30 bushels of this wonderful grain are produced yearly for each person in the United States. These 30 bushels produce much of the pork, beef, and eggs used by each person. About 50,000,000 bushels annually are exported, which help to feed other people. The United States produces more than 75 per cent of the corn crop of the world, and world price levels of corn and the products derived from it are largely set by the corn prices prevailing in the United States.

The Corn Belt is the region in which corn, hogs, beef, cattle, poultry, and horses are produced fairly economically. In fact, hog prices are controlled by the prices of hogs in the Corn Belt. Territorially these products come mostly from the Corn Belt, and the cheapness with which these products can be produced in this region can not be ignored elsewhere.

The factors increasing corn yields when judiciously employed will probably increase yields from 10 to 25 per cent and at the

same time reduce the cost of production per bushel. Increased yields per acre, efficiently and economically produced, must be the lesson taught.

LABORATORY EXERCISES AND HOME PROJECTS

1. Make a corn survey of the district. Any pupil may help in this survey. Have pupils bring the following data from the homes of every farmer in the district if possible, and record in a table like the one following:

Names of Farmers	Acres in Farm	Acres in Corn	Per Cent of Farm in Corn	Variety

2. Make a study of dent, pop, and sweet corn. With plants and ears in hand fill out a table similar to the one below:

Description of Groups of Corn

Group Name	Number of Leaves	Kind of Roots	Height of Stalks	Number of Kernels	Character of Kernels

3. Figure out, with the help of your parents, the cost of producing an acre of corn on your father's farm, using the same points as a basis to figure cost as found on p. 140.

4. Find the cost of each tool and machine used in corn production. Itemize the same. How long will the tools last? How much then do the tools decrease in value each year?

5. Examine several ears of corn and fill out the following outline. Mark thus (√) the character in its proper place.

	Characteristic (Mark √)				
1. Shape of ear					
(1) Cylindrical					
(2) Partly cylindrical					
(3) Tapering					
2. Length of ear in inches					
3. Circumference of ear one-third distance from butt to tip					
4. Color of kernel					
(1) White					
(2) Yellow					
(3) Mixed					
5. Indentation					
(1) Smooth					
(2) Rough					
(3) Creased					
6. Number of kernels					
7. Number of kernels to row					
8. Number of kernels on ear					
9. Space between rows					
(1) Close					
(2) Wide					
10. Arrangement of rows					
(1) Straight					
(2) Twist to right					
(3) Twist to left					
11. Butt					
(1) Flat					
(2) Cup-shaped					
(3) Deep					
(4) Enlarged					
(5) Compressed					
(6) Cylindrical like rest of ear					
12. Tip					
(1) Covered					
(2) Exposed					
(3) Cylindrical					
(4) Tapering					
13. Cob					
(1) Color					
(2) Size					

6. Score several ears, using the score card:

SCORE CARD — CORN

SCALE OF POINTS		SAMPLE OF VARIETY							
Trueness to type and breed characteristics:									
1. Uniformity of type	10								
2. Shape of ear	10								
3. Length of ear	10								
4. Circumference of ear	5								
5. Purity (*a*) kernel	5								
(*b*) cob	5								
	45								
Maturity and market condition:									
6. Maturity	5								
7. Market condition	5								
	10								
Yielding qualities and vitality:									
8. Character of germ	10								
9. Kernels (*a*) shape	5								
(*b*) uniformity	5								
10. Butt	5								
11. Tip	5								
12. Space	5								
13. Size of cob	10								
	45								
Total	100								

Explanation of the score card:

1. *Uniformity of type* (10). — For each ear differing in shape, color, or indentation from the type of the variety cut from one-quarter to one point. In scoring single ears cut from one to ten points according to lack of conformity to breed of ideal type.

2. *Shape of ear* (10). — Ears should be as nearly cylindrical as possible and have straight rows running from butt to tip. These characteristics

usually indicate a high per cent of corn to cob and a large number or kernels of uniform size and shape for planting. Cut one-fourth to one point for each ear that tapers too greatly.

3. Length of ears (10). — Add together the deficiency and the excess in length of all ears not conforming to the standard of the variety, and for each inch thus obtained cut one point. Should the deficiency exceed 10 inches, a cut of two points for each additional inch shall be made on the total score.

4. Circumference of ears (5). — The deficiency and excess in circumference (one-third the distance from butt to tip) of all ears not conforming to the standard of the variety shall be added together, and for each inch thus obtained a cut of one-half point shall be made.

5. Purity of kernel (5). — Kernels should be free from mixture with corn of opposite color. Mixture in yellow corn is shown on caps of kernels; in white corn on the sides. For each mixed kernel in an exhibit cut one-fourth point.

Purity of cob (5). — Cobs should be one color; in yellow corn, red; and in white corn, white. (Except St. Charles White, which has a red cob.) For pink cobs cut one-fourth to one-half point for each according to shade. One cob of the opposite color bars the exhibit.

6. Maturity (5). — Ears should be well matured, heavy, and dry, and the kernels bright and firm on the cob. For immature or loose ears cut not to exceed one-half point.

7. Market condition (5). — Ears should be free from injury or decayed spots. Ears showing rotten spots or injuries should be cut one-fourth to one-half point. A dead ear should be cut five points. Two dead ears bars the exhibit.

8. Character of the germ (10). — Germ should be full, smooth, bright, not blistered, shriveled, or discolored. When broken it should show a fresh oily appearance. Cut not more than one point for each ear showing inferior germs.

9. Shape of kernels (5). — The ideal kernel is slightly wedge-shaped but not pointed, and its length is approximately one and one-half times as great as its width at the widest part. For each ear showing kernels of poor shape, cut from one-fourth to one-half point.

10. Uniformity of kernels (5). — The kernels from the different ears should be of the same size and shape; also those in each ear should be uniform. For each ear having kernels which differ in shape or size from

the majority, cut from one-fourth to one-half point. For each ear with very irregular kernels, cut from one-fourth to one point.

11. Butt (5). — An ideal butt on an ear of corn should be well rounded out, with regular rows of deep kernels, solidly and evenly compacted around a clean cup-shaped cavity. Cut not to exceed one-half point for each defective butt.

12. Tip (5). — The tip should be filled out to the end with deep kernels in regular rows. The ideal tip is completely covered; but if kernels are deep and regular to end of cob, no cut need be made. Cut not to exceed one-half point for each defective tip.

13. Space (5). — There should be no open space between the kernels in the row either at the crown or at the cob. Cut not to exceed one-half point for each ear seriously defective in this respect.

14. Size of the cob (10). — The cob should be medium in size with diameter about twice the depth of the kernel. Too large a cob gives a low per cent of corn, while too small a cob does not favor a large yield per acre. Cut one-half to one point from each cob markedly out of proportion in this respect.

Note. — The score card is designed for scoring ten-ear samples. To score single ears, cut in tenths of points according to judgment.

7. Find out how different farmers in your vicinity store their seed corn until planting time.

8. Have the class make a corn tree and have them illustrate the method of seed storing with it.

9. Test ten ears of seed corn. Take six kernels from different places on the ear and plant in a box of sawdust or sand. Pack the sand or sawdust well. Lay over it a white cloth, marked into two-inch squares. Lay six kernels from one ear, taken from the butt, middle, and tip, in a square. Test all ten ears in this manner. Moisten well. Keep in a warm place (70° to 80° Fahrenheit) until kernels germinate. Record what you find after kernels have had time to germinate.

10. On a field trip figure the per cent of stand. There are 43,560 square feet in an acre. If corn is planted three feet and six inches each way, there are 3556 hills on an acre. (Sixteen hills square or two hundred fifty-six hills is one-twelfth acre.) There should be three kernels per hill or 768 stalks in one-twelfth acre. Count the number of stalks in sixteen hills square and divide the result by 768. This will give the per cent of stand. After the class exercise have pupils bring data from their parents' farms.

11. Select four or five ears of different types. Weigh the ears. Then shell. Weigh the shelled corn. Divide the weight of shelled corn with two ciphers annexed by the total weight of the ear. This gives the per cent of shelled corn.

DATA ON EARS

EAR NUMBER	TOTAL WEIGHT	WEIGHT OF SHELLED CORN	PER CENT OF SHELLED CORN
1			
2			

12. Take hills where two, three, or four stalks are growing. Count or approximate closely the number of kernels on each stalk. Record as follows:

PRODUCTIVE VARIATIONS OF CORN

HILL NUMBER	NUMBER OF KERNELS			
	EAR NO. 1	EAR NO. 2	EAR NO. 3	EAR NO. 4

CHAPTER XVI

OATS

History of oats. — Oats were not grown by the nations of antiquity, for we hear nothing in history about their being grown in ancient Egypt nor by the Hebrews, Greeks, or Romans.

Oats were domesticated about the time of the beginning of the Christian era, probably in eastern Europe or southwestern Asia; but their production was relatively unimportant until northern Europe became civilized. Germany, France, Belgium, Switzerland, and other European countries grew oats. Another epoch in the history of oats began when the crop was introduced into America. To-day the culture of oats is coextensive with civilization itself.

The oat plant. — This plant too belongs to the grass family. The plants are characterized by hollow stems that have nodes and internodes; roots that are fibrous and grow near the surface of the soil; and leaves that are long and narrow and parallel-veined.

Oat crop of the world. — The United States, Russia, Canada, Germany, France, Poland, the United Kingdom, and Sweden are the chief oat-producing countries (Fig. 99).

In the period since the World War, oat production has in-

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: several samples of shelled oats; scales; several heads of oats, showing the widest variation of kernels per head, produced under conditions as nearly similar as possible.

creased somewhat over the pre-war period. The banner year for oat production in the United States was 1917 when 1,592,740,000 bushels were produced.

Oat-producing states. — In the United States, as elsewhere in the world, oats thrive best in cool, moist conditions; and therefore the leading oat-producing region is found in the North Central

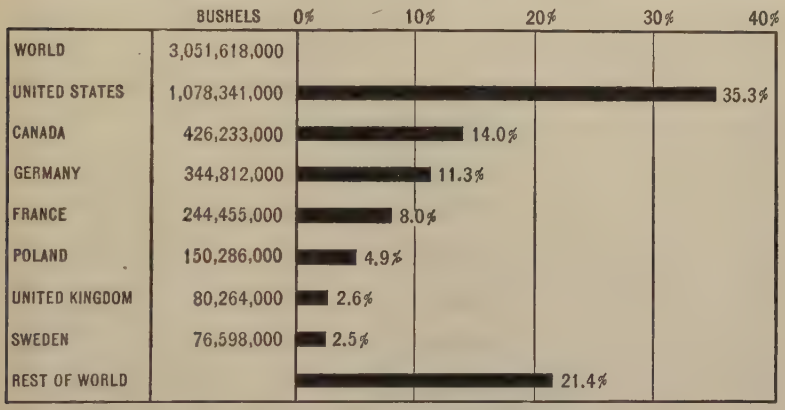


Fig. 99. — Principal oat-producing countries, 1921

States. The data and graph in Fig. 100 indicate the states where the principal part of the oat crop is produced.

The map (Fig. 101) shows the states where the oat crop was produced in 1922. The map is representative of the yields for any normal year.

Conditions for oat production. — Climate determines almost wholly where oats are grown; and climate depends upon two things: rainfall and temperature.

Oats thrive best in cool, moist soils. The heaviest yields of oats are made in cool, moist years. It has been found that it requires 504 pounds of water to produce one pound of dry matter in oats. It is for this reason that a fairly wet season

produces the best oats. Besides this, in the early periods of growth, tillering, or stooling, is best produced in moist, cool weather.

Oats grow best in a cool climate. They will thrive farther north than either corn or wheat. Norway and Sweden, Scotland, and Canada produce large quantities of oats. The center

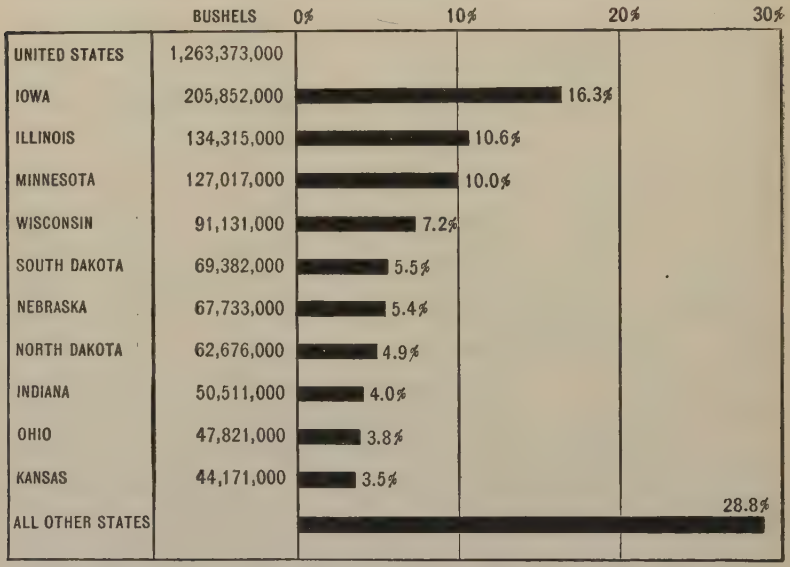


Fig. 100. — Average oat production for the three years 1920–1922

of production in the United States now is Iowa, Illinois, Minnesota, Wisconsin, South Dakota, Indiana, and Nebraska. These states make what is called the "Oat Belt." Why is it probable that they will remain the principal oat states?

Improvement of oats. — The qualities a good oat should possess are as follows: (1) tillering ability; (2) high percentage of kernels; (3) weightiness; (4) stiffness of straw; (5) resistance to rust; and (6) early maturity.

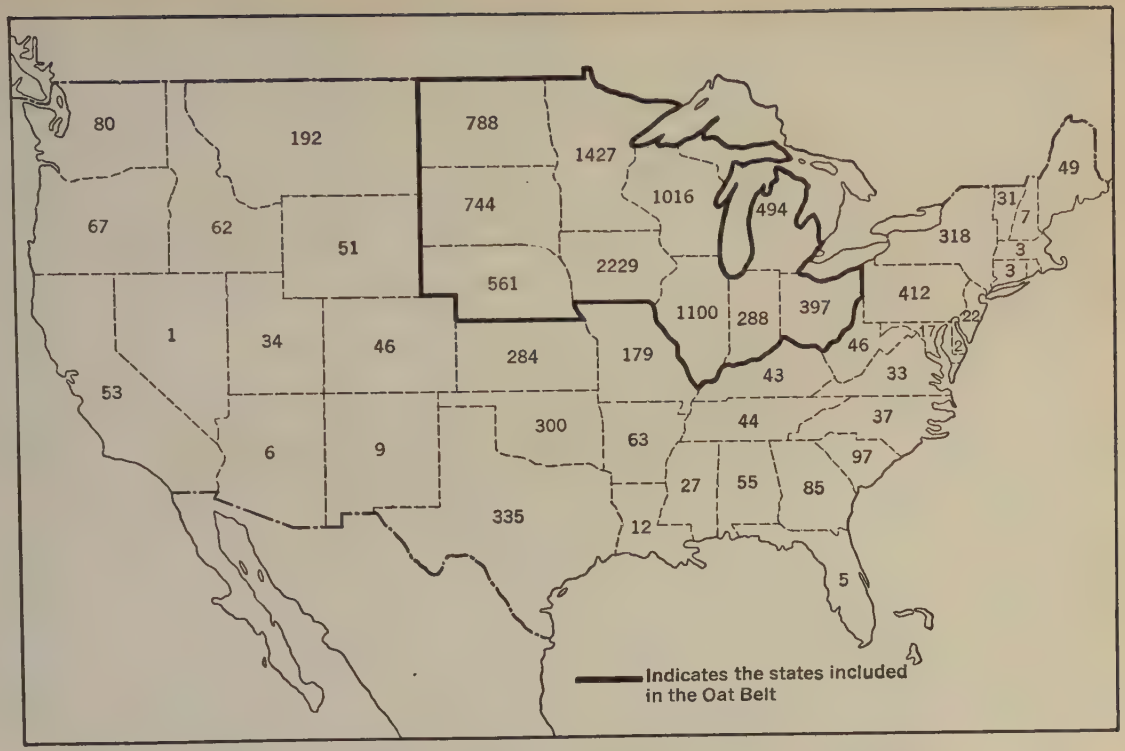


Fig. 101. — Oat production, 1922 (each unit represents 100,000 bushels)

1. Even in the same variety some kernels have a much higher capacity to *stool*, or put out additional stems, than others. Although the large factor in producing stooling is cool, moist weather, the farmer may improve the yield by selecting seed from those stems that show a tendency to stool.

2. A *high percentage of kernels* is essential to yields. Some oat stems will bear 30 kernels, some 60, and others 90 or more. Only the prolific kinds are worthy of perpetuation. Poor producers should be eliminated.

3. *Weightiness* gives oats their quality as far as real feeding substance is concerned. In most states the standard weight of oats is 32 pounds to the measured bushel. Seed oats should weigh more, for more weight indicates less hull and more kernel. A good oat will have as little as 30 per cent hull, and 70 per cent kernel.

4. *Stiffness of straw*, also, varies to some extent in oats of the same variety. There is a great deal of loss in oat production due to lodging. This may be overcome by selecting those varieties having stems that are stiff.

5. The *rusts* do untold damage to oats. They will be discussed in a later paragraph.

Average Yields of Oats Produced on an Acre

	1910–1919 (Bushels)	1919–1922 (Bushels)
Germany	47.5	41.0
United Kingdom	43.1	39.8[1]
France	32.8	31.3
Austria	29.3	25.4[1]
United States	32.1	29.4
Russia	22.2	....

[1] 1919–21.

6. *Earliness* is a quality sought in oats, because early oats are freed to a large extent from storms, insect and fungous enemies, and hot, dry weather. The number of days from planting time to maturity of 36 varieties at the Ohio Station ranged from 94 to 112 days.

Factors aiding oat production. — There are several factors which help to increase oat yields and at the same time help to reduce the cost of producing a bushel of oats. They are: (1) use of machinery; (2) proper preparation of the seed bed; (3) use of good seed; (4) sowing at the right time; (5) drilling oats; (6) rotation of crops; (7) use of adaptable and prolific varieties; (8) use of barnyard manure; (9) use of commercial fertilizers; (10) combating the enemies of oats; and (11) harvesting properly.

1. *Use of machinery.* — Oats, like wheat, are produced by machinery. Oats most frequently follow corn in rotation; and when this is the case, the seed bed is usually double-disked, harrowed, and then drilled. Hence the disk, harrow, drill, and binder are the implements used in the production of oats. After the harvested oats have stood in the field three or four weeks, the seeds are separated from the stem by the use of the threshing machine. The time and cost to produce an acre of oats with a yield of 40 bushels by hand in 1830 and by machine in 1895 are given in the following comparison: In 1830 it required $66\frac{1}{4}$ hours of hand labor to produce an acre of oats yielding 40 bushels at a cost of $3.65; while in 1865 it required $7\frac{1}{1\frac{1}{2}}$ hours to do the same work with machinery at a cost of $1.60. Thus the machine method reduced the cost to less than one half and the time to less than one ninth of that required for hand labor. In addition to the above advantages machine methods are conducive to larger yields.

2. *Proper preparation of the seed bed.* — As a rule, the seed bed for oats is given less preparation and attention than that for any

other cereal crop. Since oats fit into the scheme of crop rotation so well, since the seed bed is easily prepared, and since it is a machine-made crop, oat production is profitable.

Oats require a soil that is mellow, friable, and firm from three to five inches deep. Since loam and clay loams have a greater

Courtesy of International Harvester Co.

Fig. 102. — Drilling oats

capacity for holding water than sand, they are better adapted for oat production. Sandy soils are too dry for oat production, and compact clays are too wet and cold. Although oats will yield better than either corn or wheat in a poorly prepared seed bed, careful preparation of the seed bed will be amply repaid by increased production.

Fall plowing probably has advantages over spring plowing

because it permits the soil to warm and dry out more rapidly, and thus the oat crop may be sown earlier, an important factor in securing yields. At the Oklahoma Station, fall-plowed land yielded 34.8 bushels, and spring-plowed 32.0; at the Michigan Station, fall-plowed land yielded 49.6 bushels, and spring-plowed 42.0 bushels; at the North Dakota Station, fall-plowed land yielded 28.6 bushels, and spring-plowed 26.0. In other experiments spring-plowed soils have yielded almost as well, and sometimes better, than fall-plowed soils. Fall plowing may be recommended, for it has the advantages above indicated and facilitates work in the spring.

3. *The use of good seed.* — Pin oats, oats without kernels, and other light oats should not be sown. The number of oat kernels in a bushel varies from 352,000 to 960,000. Only heavy, plump grains should be sown. Since large oats contain fewer seeds per bushel than do light oats, slightly more of large oats should be sown per acre. Experiments at several of the Experiment Stations gave the following results:

HEAVY SEED *versus* LIGHT SEED AND YIELDS

	KANSAS STATION, 8-YEAR TEST	OHIO STATION, 7-YEAR TEST	ONTARIO STATION, 7-YEAR TEST	AVERAGE OF ALL STATIONS
Heavy seed oats .	30.9 bushels	46.3 bushels	62.0 bushels	46.4 bushels
Common seed oats	29.9 bushels	44.8 bushels	54.1 bushels	42.9 bushels
Light seed oats .	27.5 bushels	42.6 bushels	46.6 bushels	38.9 bushels

From these experiments it may be observed that heavy seed oats yielded 3.5 bushels more to the acre than common seed and 7.5 bushels more than light seed.

At the Minnesota Station[1] two bushels each of oats were sown, weighing 37 and 21 pounds respectively. The yield from the

[1] Bulletin No. 31.

heavy seed was 64 bushels per acre; and from the light seed, 55 bushels per acre.

The selection of seed oats is worthy of the close consideration of the farmer, for the additional yield from the use of heavy seed oats is almost pure profit — except it costs a little more to harvest and thresh. The yield of oat straw is also slightly increased by the use of heavy seed.

4. *Sowing oats at the right time.* — This is one of the most important factors in oat production. In the South oats are sown in the fall; in the North they are sown in the spring. Bulletin No. 424, U. S. Department of Agriculture, says: "One of the greatest essentials in growing oats is to get the seed into the ground early. The crop grows best in cool climates and in cool weather and is often materially injured by a few hot days when it is near maturity. Frosts or even hard freezes after the seed is sown seldom injure it, so that as a rule oats should be sown just as soon as the ground is in condition to work in the spring."

A few experimental records are here included, to show the relation of time of seeding to oat production:

EARLY SOWING INCREASES OAT YIELDS

VIRGINIA STATION, 4-YEAR TEST		OHIO STATION, 3-YEAR TEST	
Sown Sept. 15	30.64 bu.	Sown March 22	69.11 bu.
Sown Sept. 30	28.06 bu.	Sown April 1 to 13	64.09 bu.
Sown Oct. 15	15.32 bu.	Sown April 14 to 27	55.55 bu.

5. *Drilling oats.* — Drilling oats has several important advantages over broadcasting. Among these advantages are: (1) The seed is more evenly distributed. (2) Less seed is required. (3) Seeds are covered at a uniform depth, and therefore they germinate more uniformly. (4) Drilled oats will mature at more

nearly the same time than will broadcasted oats. (5) Drilled oats brace themselves better and will not lodge so easily. (6) Drilled oats usually yield more (Fig. 102).

At the Illinois Station in a three-year test drilled oats yielded

Fig. 103. — A field of oats in Georgia

5.3 bushels more than did broadcasted oats. At the Kansas Station in a seven-year test drilled oats yielded 3.76 bushels, or 14 per cent, more than broadcasted oats. At the Nebraska Station in a four-year trial drilled oats produced 40.1 bushels, while broadcasted oats produced only 31.4 bushels.

The depth of sowing also deserves brief consideration, for it too

affects yields. Practically all experimental data favor shallow sowing. At the Ohio Station the average of a two-year trial showed a yield of 3.56 bushels to the acre more for a 1-inch than for a 2-inch depth; and 7.73 bushels to the acre more for a 1-inch than for a 3-inch or 4-inch depth. The Illinois, Kentucky, Minnesota, and Missouri Stations found similar results; namely, that sowing oats from 1 to 2 inches deep, depending on the condition of the soil, gave best yields.

6. *Rotation of crops.* — Oats seem to be less influenced by rotation than other farm crops, yet at the Missouri Station, where grown continuously for 25 years, oats produced only 14.52 bushels; but where grown in a 4-year rotation of corn, wheat, oats, and clover, the yield was 27.3 bushels. This was an increase of almost 100 per cent. At the Indiana Station in a 15-year rotation of wheat, corn, and oats the increased yields of each were as follows: Wheat was increased in yield 50 per cent; corn, 22 per cent; and oats, 19 per cent.

The following crop rotations are commonly practiced: In the Northern states wheat, corn, oats, and clover two years; in the Southern states cotton, fall oats, peas, and alfalfa three years. In many of the Southern states a crop of oats and of peas may be taken off the same season.

7. *Use of adaptable and prolific varieties.* — Plants vary a great deal in adaptability and frequently imported seeds do very poorly until they become acclimated, and this requires two or three years. Ordinarily home-grown seeds and seeds coming from the type of soil on which the next crop is to be grown do best.

The table on p. 219 shows how oat varieties differ in productiveness. Similar data are in possession of almost every Experiment Station.

Swedish Select yielded about 26 bushels per acre more than did White Schoenen No. 153 in the 5-years' test.

No hard and fast rule can be indicated regarding the use of a variety of oats for any section of the United States, nor for any state, because soils and climate vary greatly even within a state.

VARIATIONS OF PRODUCTIVENESS OF DIFFERENT VARIETIES OF OATS

	1904 (Bushels)	1905 (Bushels)	1906 (Bushels)	1907 (Bushels)	1908 (Bushels)	AVERAGE (Bushels)
Lincoln	50.7	24.3	42.2	14.1	17.6	29.78
Swedish Select	70.0	45.3	61.6	24.1	25.0	45.2
Wide Awake No. 154	51.7	24.1	35.0	11.9	12.5	27.04
White Schoenen No. 153	46.8	20.6	19.4	00.0	8.4	23.80

8. *Use of barnyard manure.* — Generally barnyard manure is not applied to oats, for it often causes oats to lodge, and, besides that, it makes more money in the production of other crops. A ton of barnyard manure besides adding humus to the soil adds nitrogen, phosphorus, and potash. A ton of ordinary horse stable manure adds 14 pounds of nitrogen, 5 pounds of phosphoric acid, and 11 pounds of potash. Such manure is worth as much as the increased yield in oats times the price per bushel. Only about 50 per cent of the fertility of manure is taken out the first year.

9. *Use of commercial fertilizers.* — From an economic standpoint commercial fertilizers are not usually used on oats but elsewhere in the rotation where they will bring more money. Of the three elements contained in commercial fertilizers, phosphoric acid is most frequently lacking and is usually most necessary in the production of oats. Phosphoric acid hastens ripening and helps fill the grain, thereby increasing the weight and the quality. Potash makes the kernel plump and strengthens the straw, preventing lodging. Nitrogen induces the growth of foliage. Therefore, since oats are produced for their seeds, generally fertilizers high in phosphoric acid are recommended.

10. *Combating the enemies of oats.* — The total annual loss due to diseases of oats averages from 75,000,000 to 100,000,000 bushels. The principal diseases of oats are smuts and rusts. Smuts are of two forms: closed smut and loose smut. The closed smut attacks kernels only, while loose smut attacks the entire head. Both forms of smut can be prevented by the formaldehyde or the hot-water treatment. In the former treatment the seed oats are submerged in a formaldehyde solution for ten minutes. This solution is made by mixing 1 pint of formaldehyde in 36 gallons of water. The hot-water treatment consists of soaking the seed oats in hot water, 133° Fahrenheit, for ten minutes. After being soaked in either the formaldehyde or the hot water, the seed oats are spread over a floor to dry.

Courtesy of U. S. Department of Agriculture

Fig. 104. — Effect of oat smut

There are two forms of rust which attack oats. One of these is the "orange leaf" rust, which affects the leaves only and does comparatively little harm. The other form is the black stem rust, which finds lodgment on the tender oat stem, penetrates it, and then multiplies rapidly on the inside. The stems often split open, and in the black stage the plants are so devitalized that they often die without forming

any seed. Sometimes there is only a partial failure, but often a total failure results. The annual loss due to rusts exceeds 35,000,000 bushels. Moist seasons are conducive to rusts. The only preventive now known for oat rust is to develop rust-resistant varieties.

The chinch bug, army worm, and grasshopper sometimes do damage to oats. Threshed oats are less subject to attacks from insects and worms than any other of our grains. This is partially due to the hull covering of oats.

11. *Harvesting properly.* — Oats are cut when they have just passed from the milk stage into what is called the hard dough stage or just a very little later. The heads have turned yellow and the leaves are also beginning to turn. If cut earlier, the kernels shrivel and become lighter. However, the straw of oats may cure slightly better when cut a little earlier. Harvesting over-ripe oats causes some loss, due to shattering at cutting as well as at threshing time.

Oats, when cut, should be shocked immediately, for exposure to the sun bleaches the straw and the grain and reduces the quality of both. Oat shocks should usually be smaller than wheat shocks for the reason that oat straw contains more moisture. The shocks should be carefully capped to protect the oats as much as possible from dews, rains, and sunshine.

While threshing out of the shock is a very common practice and while this is quite satisfactory if the season is dry and the threshing crew may be had at the time when the oats are in proper condition for threshing, stacking oats may be recommended as good farm practice. It is estimated that it costs about one cent per bushel more to stack and thresh oats than to thresh them out of the shock, but as a rule a better quality of grain is secured by stacking. Oats, like wheat, go through a sweating process both in the shock and in the stack. Each process takes from 3 to 5

weeks. Oats should not be threshed until they have passed through these sweating processes.

The oat straw should either be put into a barn or be well stacked. Oat straw is worth from $3.00 to $6.00 per ton as a feed; hence it should be carefully guarded.

Courtesy of U. S. Department of Agriculture

Fig. 105. — Harvesting Appler oats in South Carolina

Uses of oats. — About 75 per cent of the oat crop is fed on the farms where it is grown. As food for horses oats are the best single feed grown. Oats produce more muscle and bone than corn does, and therefore they are especially adapted for animals doing work and for breeding stock and for growing animals. Since good oats contain about 30 per cent hull and since oats weigh only 32 pounds to the bushel, it requires about $2\frac{1}{2}$ bushels of oats to be equivalent to a bushel of corn in feeding value. An absolute comparison can hardly be made, because corn is more

carbonaceous and oats are more nitrogenous. The following table gives a true basis for comparison of these two excellent feeds:

DIGESTIBLE COMPOSITION OF VARIOUS FEEDS

	TOTAL DRY MATTER (Pounds)	DIGESTIBLE NUTRIENT IN 100 POUNDS				NUTRITIVE RATIO	THERMS IN 100 POUNDS
		CRUDE PROTEIN (Pounds)	CARBO-HYDRATES (Pounds)	FAT (Pounds)	TOTAL (Pounds)		
Wheat	89.8	9.2	67.5	1.5	80.1	1:7.7	91.82
Corn	89.5	7.5	67.8	4.6	85.7	1:10.4	85.50
Oats	90.8	9.7	52.1	3.8	70.4	1:6.3	67.56
Oatmeal	92.1	12.8	56.9	6.0	83.2	1:5.5	74.00
Oat straw	88.5	1.0	42.6	0.9	45.6	1:44.6	34.81

Wheat has 80 pounds of digestible material in 100 pounds; oats have 70. According to this, oats have $\frac{7}{8}$ of the feeding value of wheat. But, since the nutritive ratio of oats is as 1 : 6.3 and that of wheat is as 1 : 7.7, oats have a relatively higher per cent of protein, a very desirable thing in a feed. The heating value of wheat is 92 therms per hundred pounds and of oats it is 68. This indicates that oats have a little less than $\frac{3}{4}$ of the heating value of wheat.

On the worth of oats as a human food we repeat a story found in Hunt's "Cereals in America": "The witty Dr. Johnson sarcastically remarked, 'Oats is a grain fed to horses in England but eaten by men in Scotland.' 'Yes,' said the Scotchman, 'and I have noticed that they grow the best of horses in England and the best of men in Scotland!' "

For growing hogs oats is an excellent feed. Bulletin No. 268 of the Ohio Station found oats to have the following value in comparison with corn:

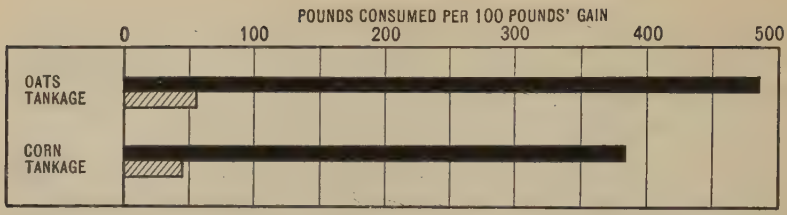


Fig. 106. — Oats and corn for fattening hogs

For hogs, calves, or cows oats should be ground before being fed.

Marketing oats. — Oats are marketed according to class and grade. They are divided on the basis of color into four classes: white, red, gray, and black oats. After an oat has been put into a class, it then falls into one of the following four grades: No. 1, No. 2, No. 3, or No. 4. The grade it falls into is dependent upon the following: (1) condition and general appearance; (2) test weight per bushel; (3) soundness; (4) heat damage; and (5) presence of wild oats or of other classes of oats. Oats too poor to go into any of the above classes are graded "Sample grade."

Oats are classified and graded by inspectors who for the most part work under the direction of the United States Department of Agriculture. These grain inspectors also classify and grade other grains.

Summary. — Oats are grown mostly in the north temperate zone, and the leading oat-producing nations are the United States, Russia, Canada, Germany, France, Poland, and England. The principal oat states are Iowa, Illinois, Minnesota, Wisconsin, South Dakota, and Nebraska. Moist, cool conditions are best suited for oat production.

The factors helpful in increasing oat yields are: (1) use of machinery; (2) a good seed bed; (3) use of good seed; (4) sowing

at the right time; (5) drilling oats; (6) rotation of crops; (7) use of adaptable and prolific varieties; (8) use of barnyard manure; (9) use of commercial fertilizers; (10) combating the enemies; and (11) proper harvesting.

Oats are a good horse, cattle, and hog feed and are used mostly on the farms where produced. About 3 per cent of the crop is used for human food.

LABORATORY EXERCISES AND HOME PROJECTS

1. Make an oat survey of your district. Every pupil may aid in this survey. Get the following data from every farmer. Keep as a permanent record.

OAT SURVEY OF DISTRICT DATE TEACHER

NAMES OF FARMERS	ACRES IN FARM	ACRES IN OATS	PER CENT OF FARM IN OATS	VARIETY OF OATS

2. What year, or years, have the farmers of your locality raised the best oat crops? Write the reasons.

3. Estimate, with the help of your father, the cost of producing an acre of oats on his farm.

4. Weigh out 50 or 100 grams of oats. Remove the hulls and weigh them. Divide the weight of the hulls by the weight of the sample. This will give the per cent of hull. Record as follows:

SAMPLE NO.	VARIETY	WEIGHT OF SAMPLE	WEIGHT OF HULLS	PER CENT OF HULLS	PER CENT OF KERNELS

5. Bring to school samples of oat plants having the widest possible variations in number of kernels in the head. Count the kernels and record your findings.

6. Judge samples of oats using the score card:

OAT SCORE CARD

SCALE OF POINTS	STANDARD	SAMPLE OF VARIETY						
1. Uniformity of grains . .	10							
2. Color	10							
3. Size and plumpness . .	15							
4. Per cent hull	15							
5. Per cent foreign matter .	15							
6. Per cent damaged grain .	15							
7. Weight per bushel . . .	20							
Total	100							

Explanation of the score card:

1. *Uniformity* (10). — Size, shape, and color. The sample should have grains uniform in size and shape and of the same shade of color. Divide the sample into two parts and by count find the per cent of grains differing in size or color from the majority. Cut one point for each 3 per cent found.

2. *Color* (10). — The color should be true to the variety, bright, free from weathered, bin-burned, or otherwise discolored grains. Divide the sample into two parts and cut one point for each 2 per cent found to be off color.

3. *Size and plumpness* (15). — Grains should be long, thick, and plump Divide the sample into two parts, separating out pin oats, those hulls which are empty, and those which have shrunken, light kernels. Cut one point for each 2 per cent found.

4. *Per cent of hull* (15). — The per cent of hull depends upon the variety, the locality in which grown, and the season. Good oats may have as little as 30 per cent hull. Separate the hull from a number of berries and estimate the per cent. Cut two points for each per cent of hull above 30.

5. *Per cent of foreign matter* (15). — Sample should be free from all weed seed, dirt, and other foreign matter. Separate these out from the sample

and estimate the per cent. Cut one point for each weed seed found and according to judgment for other foreign matter.

6. *Damaged grains* (15). — Sprouted or decayed grains have little more feeding value than so much trash. Separate out the musty, smutty, and sprouted grains and estimate the per cent. Cut one point for each per cent found.

7. *Weight per bushel* (20). — The sample should weigh at least 32 pounds per measured bushel. For each pound over 32 which the sample weighs, add one point to the final score. Cut one point for each pound below 32.

CHAPTER XVII

SOME MINOR GRAINS — RICE, RYE, BARLEY, AND BUCKWHEAT

Rice

Importance of rice. — Rice is used as a human food to a greater extent than any other crop. In China, India, and Japan it is the principal article of diet. In the United States, of course, we use wheat instead.

Rice is produced mainly in Asiatic countries, although it is grown in many other countries. Comparatively speaking, the

Courtesy of U. S. Department of Agriculture

Fig. 107. — Seed of three varieties of rice (natural size)
From left to right, Honduras, Blue Rose, and Japan.

United States does not produce much rice, a little less than ten pounds per person, though we do not consume so much. The United States actually exported in 1921 about 738,000,000 pounds and imported only about one tenth this amount.

The leading states in rice production are found in the southeastern part of the United States. The following table gives the acreage and production for a recent year.

RICE PRODUCTION IN THE UNITED STATES, 1922

STATE	ACRES	PRODUCTION (Bushels)
Louisiana	555,000	19,980,000
Texas	191,000	5,959,000
Arkansas	154,000	7,392,000
California	140,000	8,260,000
South Carolina	8,000	208,000
Georgia	3,000	72,000
Florida	3,000	75,000
Mississippi	1,000	19,000
United States	1,055,000	41,965,000

Louisiana produces about half of all the rice produced in the United States. The coastal plains of Louisiana and Texas and the lowland prairies of Arkansas seem especially well adapted to the production of rice.

Rice averages about 40 bushels to the acre in the United States. Rice in the rough as threshed weighs 45 pounds to the bushel. The milling outrun is 60 per cent; that is, a hundred pounds of rough rice will yield about 60 pounds of polished rice; in addition it will yield 4 pounds of polish, 17 pounds of bran, and 13 pounds of hulls. The total production of the United States is equivalent to about 1,692,540,000 pounds of rice in the hulls.

Growing rice. — This cereal grows best in tropical regions as it requires a long, hot growing season with a great deal of moisture. Low level soils that hold the water and that may be readily irrigated are best adapted to rice.

Rice may be drilled or broadcasted in a well-prepared seed bed. If broadcasted, the seed is harrowed in. Either method requires 55 to 80 pounds of seed per acre. The seeding period ranges from March 15 to June 15. A slightly warmer temperature is required for rice to germinate and grow than is required for wheat. After the rice is up, irrigation begins. Sufficient water is pumped on the land to destroy the weeds. After the

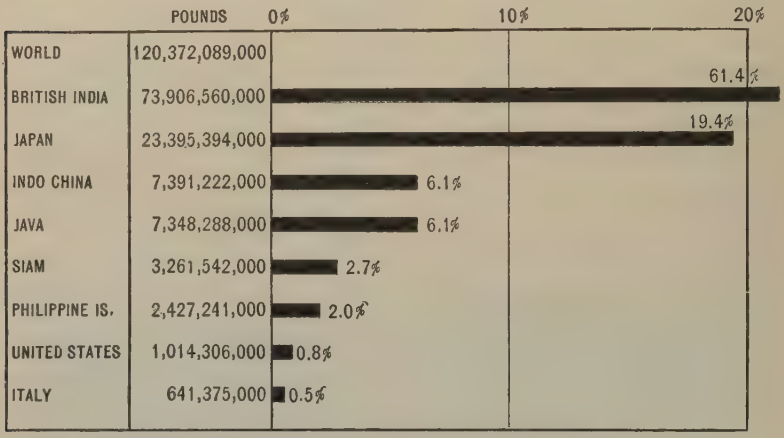


Fig. 108. — Principal rice-producing countries, 1921

weeds are killed, the water is drawn off; and as soon as the soil is dry enough, it is plowed. Then water is again turned in and in some instances is left on the ground until the crop is almost mature.

Rice is harvested a few days before it is entirely ripe. It is then shocked and well capped to protect it from rains and prevent the sun from discoloring the rice grains.

Uses of rice. — The amount of rice used in the United States per person is increasing rapidly and probably is about 7 or 8 pounds. In India there are used about 275 pounds of rice per

person per year; in Japan, 300 pounds; in most of the European countries, 7 to 15 pounds.

Fig. 109. — Harvesting rice in Arkansas

Rice has a chemical composition similar to that of wheat. The following gives the comparison:

COMPOSITION OF MILK, WHEAT, RICE, ETC.

	Dry Matter (Pounds)	Digestible Nutrients in 100 Pounds			Nutritive Ratio
		Crude Protein (Pounds)	Carbo-hydrates (Pounds)	Fat (Pounds)	
Cow's milk	13.6	3.3	4.8	3.6	1 : 3.9
Wheat	89.8	9.2	67.5	1.5	1 : 7.7
Rough rice	90.4	4.7	64.6	1.7	1 : 14.6
Polished rice	87.7	4.6	72.8	0.4	1 : 16.0
Rice bran	89.9	7.9	38.1	8.8	1 : 7.3
Rye	90.6	9.9	68.4	1.2	1 : 7.2

Rice is a fine human food, especially the rice polish and the bran of rice, which are rich in mineral matter and in the amount of protein contained. The nutritive ratio of polished rice is 1 : 16.0; and of rough rice, 1 : 14.6. The custom of stripping the kernels of wheat and rice simply removes the most valuable ingredients from these excellent foods.

Rice is prepared in various ways for the table, and it is well known that rice is highly digestible.

Rye

World production. — Europe produces about 90 per cent of all the rye produced in the world. The United States produces in average years about one third of a bushel per person.

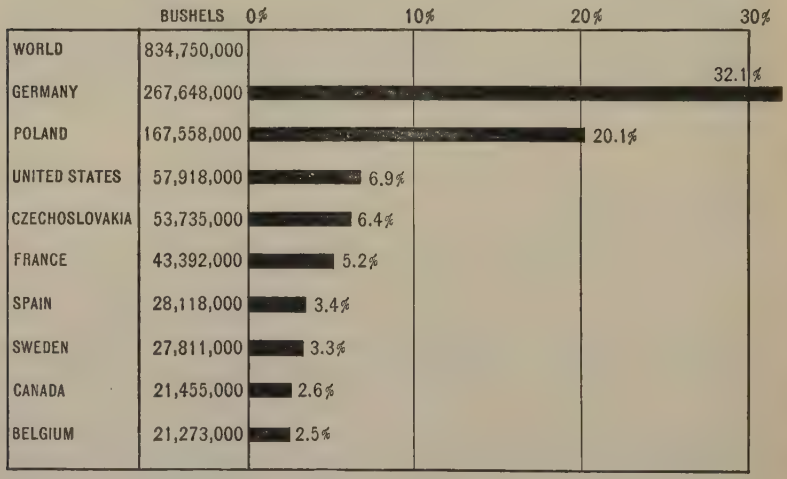


Fig. 110. — Principal rye-producing countries, 1921

The average yield per acre in the United States is about 13.5 to 14 bushels; while in Russia, Germany, and France it is 12, 25, and 18 bushels respectively. A bushel of rye weighs 56 pounds.

Rye-producing states. — Since rye grows a little farther north than wheat, it is at once evident that it is grown mostly in the Northern states. The following table shows the yield and distribution in the United States for 1922:

PRINCIPAL RYE-PRODUCING STATES, 1922

	ACRES	VALUE OF CROP
North Dakota	1,581,000	$14,704,000
Minnesota	,154,000	14,910,000
Michigan	648,000	6,303,000
Wisconsin	489,000	5,140,000
South Dakota	439,000	4,583,000
Indiana	318,000	3,015,000
Illinois	256,000	3,072,000
Pennsylvania	220,000	3,254,000
Nebraska	188,000	1,369,000
Montana	126,000	987,000
United States	6,210,000	66,085,000

Culture of rye. — Rye is a very hardy plant and will do reasonably well under adverse conditions. It grows under cooler temperatures than does wheat and on poorer soils. Rye is so vigorous that it will grow in a poorly prepared seed bed and under comparatively dry conditions.

The methods of preparation, sowing, culture, harvesting, and threshing are like those used in wheat production. A bushel and a half of seed to the acre is sown in late summer, September, or October. Rye will respond to a good soil and excellent culture just as well as any other crop grown.

Uses of rye. — Rye is grown (1) for human food; (2) for pasturage or a soiling crop; (3) for a cover and green-manure crop.

1. For human food, rye compares closely in composition with wheat and corn.

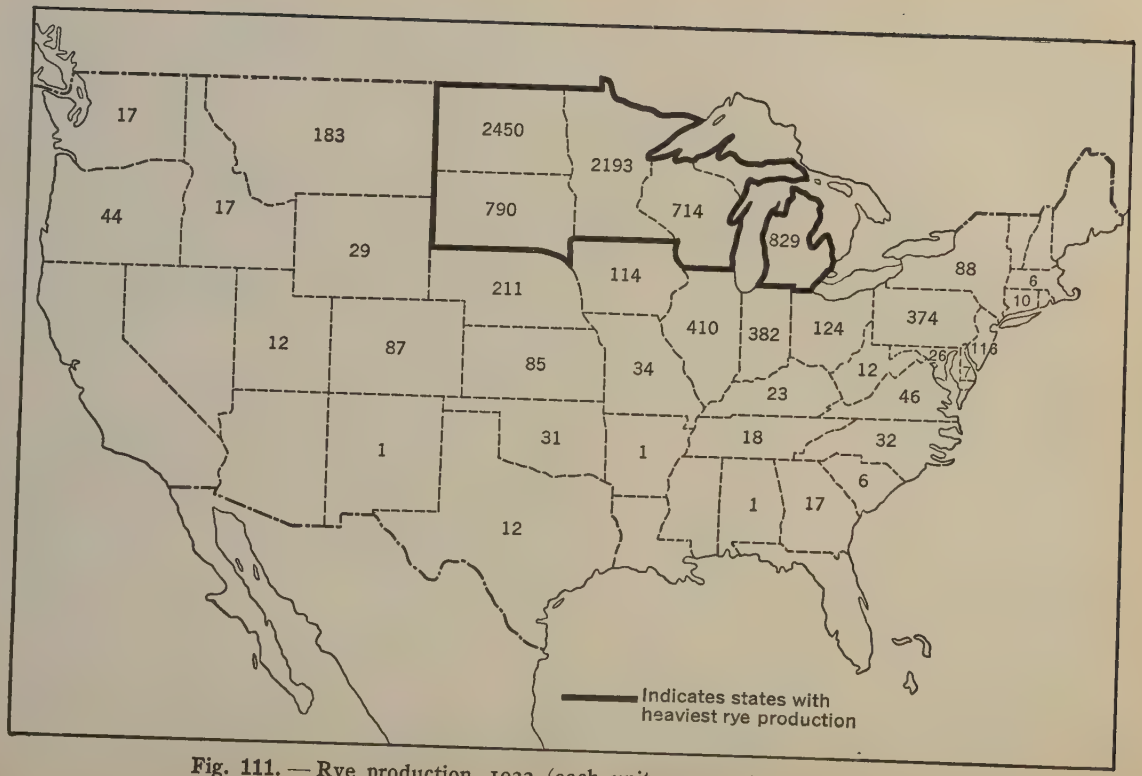


Fig. 111. — Rye production, 1922 (each unit represents 10,000 bushels)

Rye constitutes more than one third of the grain ration of the people of Europe. The production and use of rye in European countries considerably affect the price of rye produced in the United States.

2. Rye is often sown for its pasturage value. If sown in the latter part of July on a fertile, well-prepared seed bed, it will yield a great deal of pasturage for calves, cows, sheep, poultry, and hogs during the late fall, winter, and early spring. And if the grazing is allowed only when the soil is reasonably dry, it will not reduce materially the yield.

Rye is sometimes grown as a soiling crop. A soiling crop is one which is allowed to grow almost to maturity, then is cut and hauled out, while it is still green, to be fed to live stock. Rye will yield a great deal of feed as a soiling crop.

3. As a cover and manure crop rye is excellent, because it grows in the fall, winter, and spring when many crops will not grow. Rye, when so grown, holds and protects the soil; and when plowed under, it will add humus and organic matter to the soil.

Barley

Barley, a member of the grass family.— Barley, like rye, corn, wheat, oats, blue grass, and sugar cane, is a grass. It is very much like the wheat plant. The stem is jointed and hollow; the leaves, though a little wider, are parallel-veined; and the head has either two or six rows. Many beardless varieties have been developed.

Where barley is grown. — Let us consider this topic from two standpoints: first, from the standpoint of world production; and, second, from the standpoint of its production and distribution in the United States.

World production is shown in the following table:

World Production of Barley, 1921

	Bushels
World	1,137,427,000
United States	151,181,000
Japan (Empire)	124,611,000
British India	117,040,000
Spain	89,320,000
Germany	89,056,000
Canada	59,709,000
Poland	56,204,000
Algeria	48,226,000
Rumania	47,619,000
Czechoslovakia	47,471,000

Europe produces nearly one half of the entire crop of the world, and North America produces only about one half as much as Europe.

Barley is grown in the Northern, central Western, and Pacific states. Fig. 113 shows the approximate acreage devoted to this cereal in the United States in 1922.

Annual Average Yields of Barley, 1920–1922

	Bushels
California	31,771,000
South Dakota	22,212,000
Minnesota	21,712,000
North Dakota	20,741,000
Kansas	17,791,000
Wisconsin	13,592,000
Nebraska	5,565,000
Illinois	5,229,000
Michigan	4,543,000
Colorado	4,423,000

The table shows that California, South Dakota, and Minnesota rank first, second, and third respectively in the number of bushels grown.

Culture of barley. — The culture of barley is like that of wheat and oats. Barley is usually sown in the spring. Where both

From Duggar's Southern Field Crops

Fig. 112. — Four types of barley

From left to right, hooded, Arlington awnless, two-rowed, and six-rowed.

crops are sown on the same farm, oats is usually planted first. The seed used per acre varies from 6 to 12 pecks, 8 pecks being the average. A bushel of barley seed weighs 48 pounds.

Uses of barley. — Barley has been used mostly in the United States for malting purposes and for horse feed. With the enactment of prohibition the use of barley for malt is rapidly declining, and it is being increasingly used as feed for horses, dairy

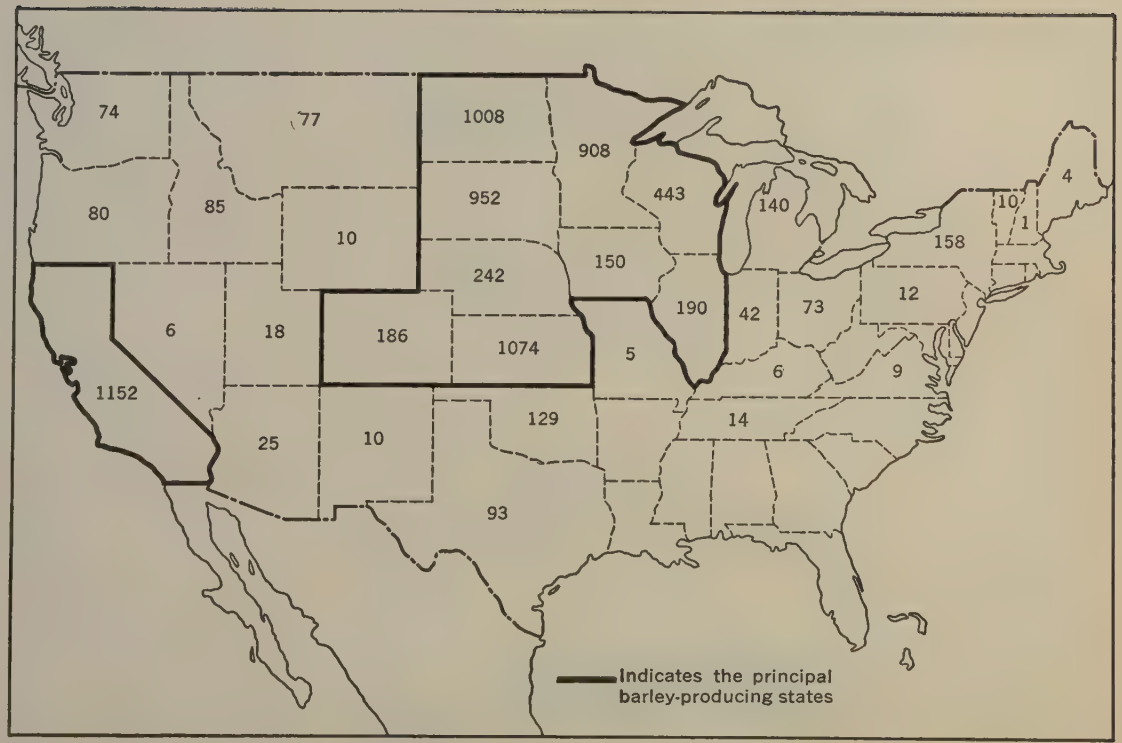


Fig. 113. — Barley acreage, 1922 (each unit represents 1000 acres)

cattle, and poultry. When used for cow feed, it is generally crushed. The feeding value of barley is similar and almost equivalent to that of wheat and corn. It has a digestible nutrient composition similar to the other grains but stands a little higher in its ash content. Its nutritive ratio is almost exactly like that of wheat.

Buckwheat

Origin and history. — Buckwheat apparently originated in Central Asia about 2000 years ago. From Asia it was distributed to Europe and America. It is now grown mostly in northern Asia, Europe, Canada, and the northeastern part of the United States.

Description of the plant. — Buckwheat does not belong to the grass family, but to the dock family. The buckwheat plant is unlike the grasses because the roots are not fibrous. There is a long taproot, and the stems, growing two and one-half to three feet tall, have lateral branches. Buckwheat does not tiller, but on account of the branching stem buckwheat should not be sown too thickly.

Buckwheat Production of Principal States, 1921

	Bushels
United States	14,207,000
Pennsylvania	5,175,000
New York	4,150,000
West Virginia	682,000
Michigan	624,000
Wisconsin	596,000
Ohio	525,000
Minnesota	448,000
Virginia	357,000
Maine	351,000

Buckwheat production. — The acreage devoted to buckwheat in the United States ranges from 700,000 to 1,000,000 acres. In 1921 there were but 680,000 acres planted and the yield was 14,207,000 bushels. The average yield per acre for the entire country is about 18 bushels, but in 1921 it was nearly 21 bushels.

© *Keystone View Co.*

Fig. 114. — Buckwheat in blossom on a Pennsylvania farm

Culture of buckwheat. — Buckwheat responds to good culture, although it will grow on rather poor soils and on soils which are lacking in lime and drainage. Therefore it is extensively grown on the hills of the Northeastern states. A bushel of buckwheat weighs 48 pounds, and it requires from 3 to 5 pecks to sow an

acre. Buckwheat matures in 60 to 70 days; and since it is harvested just before frost, it is sown just in time to mature in late summer and early autumn, because the fall climate is best adapted for its growth.

Uses of buckwheat. — Most of the buckwheat is used for human food, although some is used for feed for dairy cows, hogs, and poultry. In milling, a bushel of buckwheat yields 25 pounds of flour, 12 pounds of middlings, and about 11 pounds of hulls. Buckwheat flour is used in making griddle cakes. It is whiter than whole-wheat flour and it has a softer feel.

Buckwheat is often sown as a crop for honeybees, for it is well known that the flowers will yield a superior honey. In some sections buckwheat is used as a green-manure crop.

Summary. — Rice is an important food crop. Over half of the people of the world use rice as their principal food. Rice contains as much nourishment as does wheat.

Rye, barley, and buckwheat are important crops in other sections of the world as well as in the United States. While their food value is much like that of wheat, yet some dainties are made from them that are very palatable and attractive, and they may be served in a variety of ways. It is fortunate that these are domesticated plants because they are adaptable to some soils and weather conditions to which other food plants are not adaptable.

LABORATORY EXERCISES AND HOME PROJECTS

1. Have pupils grow in the school garden or in their home garden a small quantity of rice, rye, barley, and buckwheat. Let some of the plants and seeds grown be brought to school and, later, be used as laboratory material. Study the roots, stems, leaves, and seeds of each of these plants, noting similarities and differences.

2. Discuss rye bread and buckwheat cakes as to color, texture, taste, and food value.

CHAPTER XVIII

SUGAR PRODUCTION

Use of sugar. — The people of the United States consume more sugar than the people of any other nation. According to the United States Yearbook of Agriculture, the average amount used per person in the United States for the years 1911–1915 was 84 pounds per year; for the years 1916–1920 it was 83 pounds, and for 1921 it was 98 pounds. For the entire period 1900 to 1923 the sugar used per person per year was about 80 pounds. The people of England use about 65 pounds of sugar per person a year, and the people of Spain about 28 pounds, while the people of Greece, Italy, and Turkey use only 7 or 8 pounds. These figures probably represent extremes of consumption for civilized peoples.

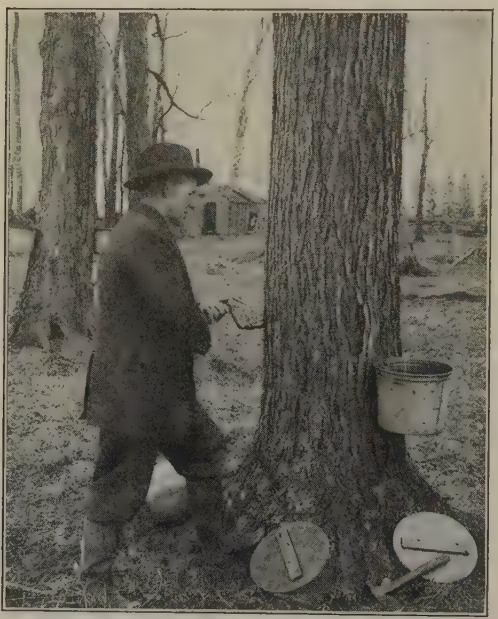


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Fig. 115. — Tapping a sugar maple

There are four sources of sugar in the United States. These sources are: the sugar cane, the sugar beet, the sugar maple, and the honeybee. Because of their greater importance in agriculture, only the first two sources will be discussed.

Sugar Cane

Sugar cane.— The sugar-cane plant gathers from the soil through its immense root system the water required in the plant; and from the sunshine, through its large leaf system, the sun's

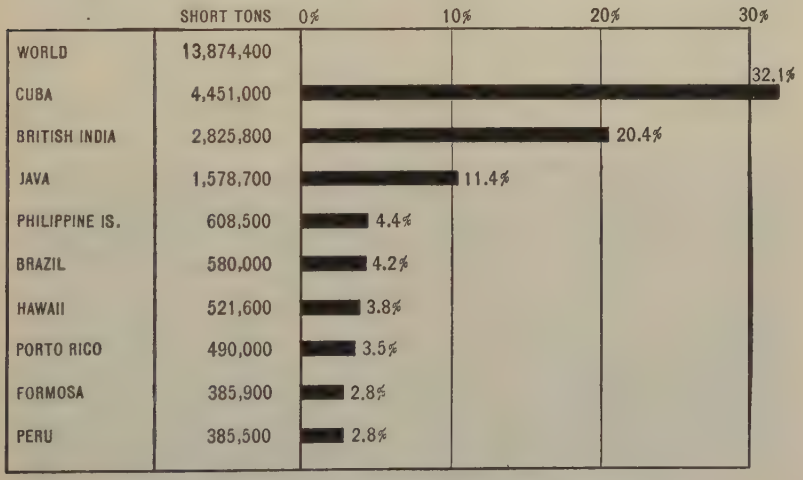


Fig. 116. — Principal sugar-cane producing countries, 1921

rays, the final source of all energy; and these are combined by the plant and made into sugar. While the sugar-cane plant is adaptable, yet, since it thrives best in the tropical regions, it is also quite evident that it requires the hot sunshine and a long summer to do its work in manufacturing its sugar content. The sugar factory does not manufacture sugar at all. It only extracts what the sugar-cane plant and the sunshine have put there.

Good sugar cane as it comes to the mill in the tropical countries contains up to 20 per cent of sugar, and the average sucrose extracted ranges from 10 to 14 per cent. The sugar mills are very efficient, extracting from 95 to 97 per cent of the sugar in the cane.

Sugar cane is planted in rows five to six feet apart, and the distance apart in the row varies from 18 to 30 inches. The object in planting far apart is to let in the maximum amount of sunshine

Fig. 117. — Harvesting sugar cane

so that a maximum amount of sugar may be stored up in the canes; this requires a lengthy season of long, sunshiny days. It requires about two inches of rain per week to mature a crop.

Sugar cane should not be harvested until it is well matured and entirely ripe. This insures not only the maximum amount of sugar, but sugar of a better quality. The canes lose their sugar content rather fast after cutting. Therefore, it should be milled

just as soon after harvesting as possible. In 1921 Louisiana produced 169,127 short tons of sugar cane; and Texas, 6,987 short tons. A short ton is 2000 pounds, and a ton of sugar cane yields 150 to 180 pounds of sugar. The average yield per acre in 1921 in Louisiana was 18.5 tons; a 15-ton yield is considered good.

In the manufacture of sugar the stripped canes are put through heavy rollers which press out the juice. This juice contains the sugar in solution. To this extract of cane juice a small amount of lime is added. The impurities, such as potash and phosphorus, combine with the lime water. After this, the solution is skimmed and filtered. In this process the sugar solution is entirely separated from the other products. Then the sugar solution is concentrated by vacuum pans and evaporation. Finally the sugar crystallizes. After the sugar is dried, it is packed and ready for the market. Molasses is a by-product of sugar manufacture.

Sugar and molasses as foods provide heat to the body and, besides, are fat-producing.

Sugar Beets

Sugar beets. — As a source of sugar, the sugar beet excels the sugar-cane plant in this country. Since 1910 the sugar-beet industry has grown rapidly and far surpasses the growing of sugar cane. In 1921 the amount of sugar produced from beets grown in the United States was 1,020,000 tons; while the cane sugar amounted to only 324,431 tons. Germany is the greatest producer of beet sugar; the United States is a close second.

The sugar beet is closely related to the garden beet and mangel and therefore requires the same kind of culture. Sugar beets grow best in a sandy loam. Good preparation of the seed bed is absolutely essential, and thorough cultivation helps to increase the yield. The seed is planted in rows from 20 to 28 inches apart, and the plants are chopped out so that each beet has from 10 to

14 inches of space to grow in. It requires 20 pounds of seed to plant an acre.

Two conditions of climate are essential in the growing of beets. First, they require a rather cool temperature; a temperature of about 70° Fahrenheit is preferred. Extremely hot weather is unsuited to sugar beets. Second, they require a dry harvest time.

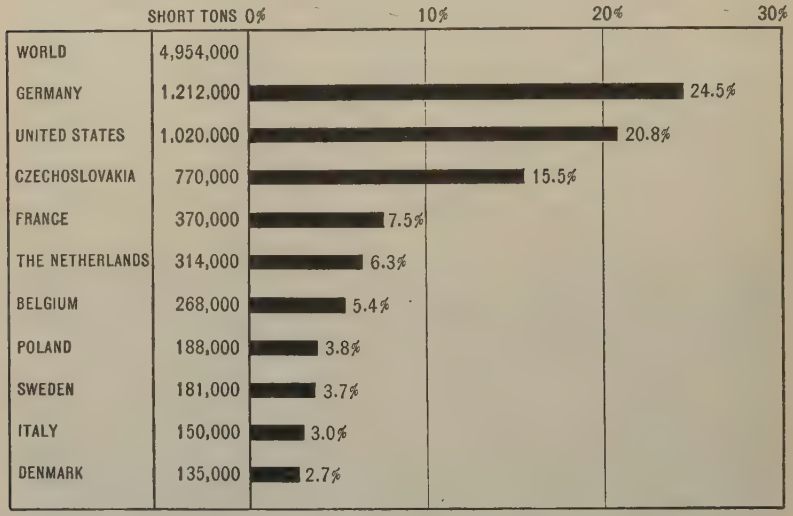


Fig. 118. — Principal sugar-beet producing countries, 1921

An excess of moisture about the time of harvesting causes the beets to take on a new growth and reduces materially the sugar content. Beets yield their highest sugar content when harvested in dry, sunshiny weather and at the close of a bright, clear day. After five or six days of cloudy, rainy weather, the sugar content is always low.

Beets have been bred up in sugar content. In 1851 beets tested 7 or 8 per cent sugar; but through breeding and selection, they have been improved until now some beets yield as much as 26 per

cent. The average content of sugar ranges from 14 to 18 per cent, though entire fields have been known to yield 22 per cent.

Sugar beets yield from 9 to 12 tons per acre. The price of beets at the factory often ranges from $10 to $12 per ton; in 1921, it was only $6.32 on the average. The cost of producing an acre of beets varies and ranges as high as $50 or $60, because there is

Fig. 119. — Sugar beets growing in Colorado

so much hand work connected with the culture and harvesting of the crop.

It is quite frequently true that the cost of production is greater than the value of the crop at harvesting time. But after the crop is once produced, it is still better to save and sell the crop and have only a partial loss than to lose the entire crop by not harvesting it.

In the states of Utah and Idaho, based on the reports of 220 farmers, it cost $11 a ton or less to produce beets. The average cost of producing a ton was $9.49. The highest cost was $35 and the lowest $5. The quantity raised per acre affects materially the cost of a ton produced, because, if 12 tons are raised per acre, the cost is likely to be materially less than if only 3 tons are produced. The objective is to produce as many beets of a good quality as possible at the lowest cost per ton.

The sugar-beet factories are found in the regions where the beets are grown; for it is economically impossible to ship raw beets far because of their high moisture content.

There are now 106 sugar-beet factories in the United States, Michigan having 17, Utah 18, Colorado 17, California 19, Idaho 8, and Wisconsin 5; these states are the leaders in sugar production.

Summary. — Sugar constitutes a considerable part of our food. Its food value consists in its power of keeping the body warm and of producing fat. Sugar is made from sugar cane and from sugar beets. The United States has land adaptable to the growing of both sources of sugar. The South grows sugar cane, and the West and North grow sugar beets.

LABORATORY EXERCISES AND HOME PROJECTS

1. Test, by experiment or otherwise, the adaptability of your locality for the growing of sugar cane and sugar beets.

2. Find from a recent issue of the United States Yearbook of Agriculture all you can about sugar cane and sugar beets in the United States.

CHAPTER XIX

RED CLOVER

History and importance of red clover. — Red clover originated in Persia, whence it was imported into Europe. Spain, Holland, and Italy grew it in the fifteenth century. Red clover was first grown in England about 1633. Pennsylvania began to grow red clover in 1770, being the first state to grow it. Now it is grown in every state of the Union. The clover district is in the North Central States — north of the Ohio River and east and north of the Missouri River. The largest centers for red clover seed are Chicago, Cincinnati, Toledo, and Detroit. In 1922 there were 1,875,000 bushels of clover seed produced. The average production was 1.7 bushels per acre.

Cultural methods and kind of seed to use. — Red clover is frequently sown during the early spring in growing wheat. When the soil is in the "honeycomb" condition, caused by freezing and thawing, is a good time to sow, for the seed is then covered by the alternate freezing and thawing of the soil. The seeds germinate at the opening of spring. From 8 to 15 pounds of seeds are sown to an acre. The amount to sow depends upon the size of the seeds (there being from 12,000,000 to 25,000,000 seeds in a bushel) and upon their germinating power. No seed should be sown un-

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: several pint samples of red-clover seeds, a red-clover plant showing nodules, a pint sample each of seeds of white, crimson, and alsike clover. These may be kept for several years.

less it will grow to the extent of 80 to 85 seeds to a hundred. Sowing clover early has the advantage that the hard, heavy seed coat is softened and broken down to a considerable extent by the rigorous weather. This insures a higher per cent of germination.

Fig. 120. — Red-clover leaves and blossoms

Red clover is sometimes sown in oats, but it generally grows better in wheat. There are two reasons for this: Oats are thicker on the soil and shade the ground; the oat crop draws very heavily on the soil moisture. There are two ways by which clover may be sown with oats to advantage: (1) by sowing from 4 to 6 pecks less of oat seed, thus giving the clover more room and water, and (2) by having sheep or cattle graze the oats down when they are 14 to 20 inches tall. Grazing very closely often injures the clover.

The seed used should be uniform in size, bright in color, large, plump, and free from weed seed and foreign matter. Home-grown seed is generally preferable to imported seed. Frequently very harmful weeds are introduced upon a farm by using seeds

that contain weed seed. After weed seeds get a start in a hay crop, they are scattered by the cattle all over the farm. Therefore all seed should be carefully examined before it is purchased to see that it is free from seeds of harmful weeds.

Courtesy of Missouri Experiment Station

Fig. 121. — Red clover responds well to treatment

When lime alone was used, the production was 1600 pounds per acre (at right); when the soil was limed and fertilized, the yield was 2550 pounds per acre (at left).

Causes of red-clover failures. — The following are the main causes of red-clover failures.

1. Seeding upon an improperly prepared seed bed is one of the first causes for red-clover failures. Sowing red clover upon hard compact soils means almost sure failure. Red clover should be sown upon mellow, rather firm soils and about $\frac{1}{2}$ to $1\frac{1}{2}$ inches deep.

2. Red clover will not grow well upon a soil that lacks humus; hence a thin coating of manure will often produce results in get-

ting a stand, which is one of the prime essentials in successful red-clover production.

3. In many instances red clover does not succeed because of the lack of lime. It will not grow well in an acid soil. Applications of $1\frac{1}{2}$ to 2 tons of ground limestone or about one half that much burned lime per acre will correct this deficiency.

4. Red clover will not grow in a water-logged soil. It prefers deep, porous, open soils — clay soils first, black loams next, and sandy soils last.

5. Red-clover sickness is a term which has caused much confusion, for to it were attributed all the failures of red-clover production. There is no specific enemy causing clover sickness. Red-clover failures are due to the following things, as summarized by Hunt in "Forage and Fiber Crops in America": (1) fungous diseases; (2) insect enemies; (3) lack or exhaustion of one or more essential elements, particularly potash; (4) unfavorable physical properties of the soil and subsoil; (5) acidity of soil; and (6) lack of tubercle-forming and nitrogen-gathering bacteria.

Some advantages in growing red clover and other legume crops. —Legume crops include the clovers, alfalfa, cowpeas, and soy beans. Although some of them are more profitable under certain conditions than others, the growing of each has the following advantages for the farmer: (1) They all take free nitrogen from the air and add it to the soil. (2) They all have long taproots and can therefore get some of their plant food from the lower strata of the soil. In this way they open up the soil deep down and improve its physical condition. (3) They store up a large proportion of protein and are therefore helpful in balancing the ration for all kinds of farm animals. (4) By rotating legumes insect life is checked.

1. The legumes replace the nitrogen taken from the soil by other crops. Every farmer boy has observed the "nodules"

that grow on the roots of leguminous crops. These nodules are full of bacteria. They gather nitrogen from the soil air and store it in the legume plant. Conditions that help bacterial growth should, therefore, be provided as far as possible by the farmer. (See p. 21.)

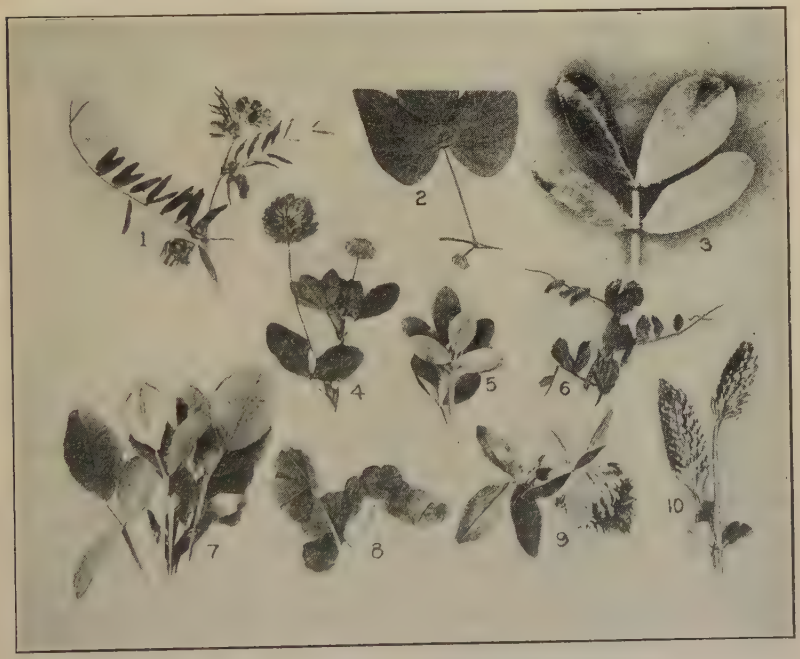


Fig. 122. — Leaves of some leguminous plants

1. hairy vetch; 2. velvet bean; 3. peanut; 4. alsike clover; 5. alfalfa; 6. field pea; 7. sweet clover; 8. bur clover; 9. red clover; 10. crimson clover.

A medium-dry, fairly warm soil which contains plenty of well-decomposed organic matter will stimulate the bacteria. The use of leguminous crops in maintaining the soil nitrogen is the most economic method. (See Fig. 134.)

2. The long taproots of the legumes gather plant foods from greater depths than other crops and therefore rest the surface soils. The growing taproots open up the subsoil, and upon decay leave the subsoil open. They also bring from the subsoil to the surface plant foods which may be used by other crops. The decay of roots aids percolation and capillarity of soil water.

3. The legumes are rich in protein and for this reason balance other feeds. The following table illustrates the difference in the *digestible* components of corn silage and some legume hays:

	Dry Matter (Per cent)	Protein (Per cent)	Carbohydrates (Per cent)	Fat (Per cent)	Nutritive Ratio
Corn silage	26.3	1.1	15.0	0.7	1 : 15.1
Alfalfa hay	91.4	10.6	39.0	0.9	1 : 3.9
Cowpea hay	90.3	13.1	33.7	1.0	1 : 2.7
Soy-bean hay	91.4	11.7	39.2	1.2	1 : 3.6
Red-clover hay	98.1	7.6	39.3	1.8	1 : 5.7

Examine carefully the column marked "Protein." See how much more protein there is in red clover than in corn silage. The nutritive ratio in corn silage is 1 : 15.1 and in cowpeas it is 1 : 2.7. The legumes are rich in nitrogen and protein and therefore help to make a well-balanced feed when used with corn or oats, which contain fats and carbohydrates. Carbohydrates and fats produce heat and energy; proteins build tissue, bone, muscle, and cell walls.

4. Legumes check insects which are injurious to our most important crops Chinch bugs, Hessian flies, and the corn-root worm do not eat leguminous crops. Where legumes are in the regular crop rotation, insect and fungous pests largely disappear.

Making clover hay. — What is the best time to cut clover and cure it for hay? At what stage of its growth will it contain the

most food nutrients and be the most palatable? The following table answers these questions:

YIELD AND NUTRIENTS IN AN ACRE OF RED CLOVER

STAGE OF GROWTH WHEN CUT	YIELD OF HAY PER ACRE (POUNDS)	ASH (POUNDS)	CRUDE PROTEIN (POUNDS)	CARBOHYDRATES		FAT (POUNDS)
				FIBER (POUNDS)	NITROGEN-FREE EXTRACT (POUNDS)	
Heads in bloom	4210	260	539	1033	1731	116
Some heads dead	4141	226	469	1248	1379	106
Heads all dead	3915	208	421	1260	1378	94

This table shows that there is a greater yield of ash, crude protein, and fat, when clover is in bloom than at any later period. This would indicate that the best time to cut clover for hay is when most of the heads are in bloom. However, it is probably best to cut clover when from one fourth to one third of the heads are turning brown. Clover should be put in small cocks before the leaves get so dry that they are lost in handling, for the leaves contain a great deal of splendid feed. After hay has stood in cocks one or two days according to the weather, they may be opened into a few large flakes. When hay is fairly dry, it should be stored in a dry haymow. Even if hay is put into the mow when a little green, it will cure up in good shape, for a bulk of hay will produce enough heat to destroy all germs. Hay from clover in which all the heads are dead does not give palatable food. According to the 1920 Census, the average acreage yield was 1.36 tons. Under exceptionally favorable conditions of soil and season from 2 to 3 tons of hay may be secured from two cuttings of clover.

For cattle alfalfa hay alone excels red-clover hay among the roughages. Tests on clover hay and timothy hay for feeding

two-year-old steers were made at the Indiana Station and the Missouri Station.

CLOVER HAY *versus* TIMOTHY HAY FOR FATTENING STEERS

		Daily Gain (Pounds)	Feed for a 100-Pound Gain	
			Corn (Pounds)	Hay (Pounds)
Lot I	Clover hay, 9.8 pounds Shelled corn, 21.5 pounds	2.4	919	410
Lot II	Timothy hay, 6.4 pounds Shelled corn, 18.8 pounds	1.8	1086	380

In the feeding trial at the Missouri Station corn was worth 8 cents per bushel more when fed with clover than with timothy hay. In each case the cattle ate more when fed clover hay, but made more economic gains.

Red clover as pasture. — Experiments seem to show that the greatest amount of food at least cost can be had from some hay crops by using them for pasturage. At the Missouri Station the following results were obtained from an acre of clover forage. The grain fed the swine was corn.

RESULTS WITH RED-CLOVER FORAGE

	Number of Days Pastured	Number of Hogs per Acre	Gain per Acre (Pounds)	Grain Per Acre (Pounds)	Gain Accredited to Forage (Pounds)	Grain per Pound Gain (Pounds)	Value of Clover Forage per Acre Pork @ 6 ¢
Lot I	147	13	1372	4330	598.2	3.16	$35.89
Lot II	119	9.5	1050	2872	537.2	2.74	32.23
Average	133	11	1211	3601	567.7	2.95	34.06

It will be observed that the grazing period was almost $4\frac{1}{2}$ months; that the number of hogs per acre was 11; that the gain per acre of forage was 567.7 pounds of pork, and that the grain fed per pound of gain was 2.95 pounds. The value of pork produced per acre from the clover forage at 6 cents per pound

Courtesy of International Harvester Co.

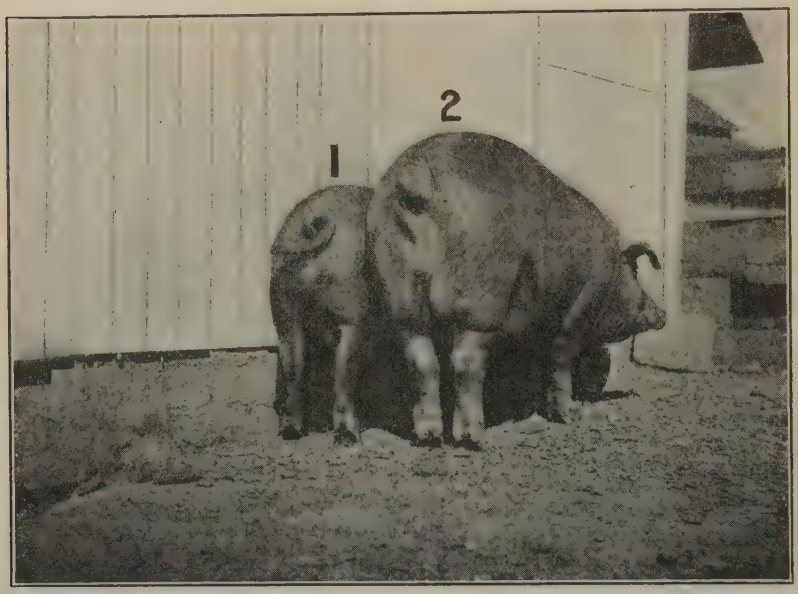
Fig. 123. — A ton of red-clover hay contains 75 pounds of lime

was $34.06. In the experiment the clover was from 6 to 8 inches high when the hogs were turned on it. Too close pasturing should not be permitted where clover is to be used for forage.

Some of the advantages of this practice are: (1) It reduces the cost of pork production. (2) It harvests the crop in a fairly economic way at little cost. (3) It tends to maintain the fertility of the soil. (4) It produces more pork on less land.

(5) W. A. Henry says, "For pigs, clover furnishes sufficient food for maintenance so that all the grain fed goes for gain."

Summary. — Red clover is a native of Persia. It was brought to the United States about 1770. It is one of the legume crops



Courtesy of International Harvester Co.

Fig. 124. — Effect of good and bad feeding

No. 1, weighing 50 pounds, was fed corn in a dry lot from a self-feeder. No. 2, weighing 54 pounds, was put on clover pasture and fed corn and tankage from a self-feeder. Both had salt, minerals, and plenty of water. After 110 days No. 1 weighed 118 pounds and No. 2 weighed 223 pounds.

and is valuable in improving the soil. Red clover grows best in a well-drained, porous, sweet soil. It makes a splendid hay or forage crop because of its large protein content. The leaves should be carefully saved when hay is made. Red clover has proved to be an excellent pasture crop in producing pork, and for cattle is only excelled by alfalfa among the hay crops.

LABORATORY EXERCISES AND HOME PROJECTS

1. Find the number of acres of red clover in your school district. Record data as follows. All pupils may help in getting data.

RED-CLOVER SURVEY DATE TEACHER

NAMES OF FARMERS	ACRES IN FARM	ACRES IN CLOVER	PER CENT OF FARM IN CLOVER	TONS OF HAY PER ACRE LAST YEAR

2. Draw and describe red-clover seed.

3. Make a germination test of purple and yellow clover seeds. Count out fifty yellow and fifty purple seeds. Make a germination test between two blotters laid on a plate to see which will grow better.

4. From several samples of clover seed find the per cent of foreign seeds. Take about one hundred or one hundred fifty seeds and by count find the per cent of weed seeds.

5. Identify, draw, and describe at least half a dozen weed seeds found in samples of clover seed.

6. Dig up a red-clover plant. Wash off the dirt carefully. Examine and draw the nodules found on the roots.

CHAPTER XX

OTHER CLOVERS

White Clover

Characteristics. — This perennial legume grows in lawns, pastures, fields, and by roadsides in both Europe and America. It is propagated by seeds and by runners which root freely at each node. The seeds are hard and pass through the digestive tract of animals without being damaged. They are reddish yellow, small, heart-shaped, and sometimes lie in the soil several years before they germinate. White clover is adaptable to a wide range of conditions and is, therefore, found in almost every part of the world. It grows best in a fairly moist, sweet, well-drained soil. It is desirable in blue-grass pastures because it grows well in midsummer when blue grass does not and it feeds at a greater depth and stores nitrogen in the soil. White clover is seldom seeded alone; from 2 to 4 pounds of seed is sown with other pasture grasses. Its creeping nature and its proportion of

Fig. 125. — White clover
The branch shows how new plants are formed.

hard seeds cause it to become permanently set. Every pasture where white clover will grow should contain it; first, because it stores nitrogen in the soil; second, because it furnishes more protein to the grass ration; and, third, because it feeds at a greater depth than do most pasture grasses.

Alsike Clover

Description. — Alsike clover originated in Sweden near Alsyke, from which it gets its name. It is a perennial which lives from 3 to 5 years. It will grow in acid soils and in wet places where red clover will not grow. Alsike makes an excellent hay because it has a smaller stem and is more easily cured than red clover. When sown in a mixture with other grasses, from 4 to 6 pounds of seeds are usually sown per acre. It has a white pinkish flower and purple or yellowish green heart-shaped seeds a little larger than white-clover seeds.

Fig. 126. — Branch of alsike clover

Crimson Clover

Description. — This annual legume grows only in warmer latitudes and, therefore, is not grown where there are hard freezing winters. In the United States it is grown most extensively along the Atlantic Coast. Crimson clover stools

From Duggar's Southern Field Crops

Fig. 127. — Crimson-clover field

The bare spot resulted from planting hulled seed; the heavy growth on each side was from unhulled seed.

readily. The seeds are larger than those of the rest of the clovers and are a shiny crimson color (Fig. 128).

Lespedeza

History and use. — Lespedeza, or Japan clover, had its origin in Japan and was probably accidentally introduced into South

Carolina where it was first observed in 1849. Japan clover now grows over the entire South and westward to Texas and Oklahoma and northward up to the Missouri River.

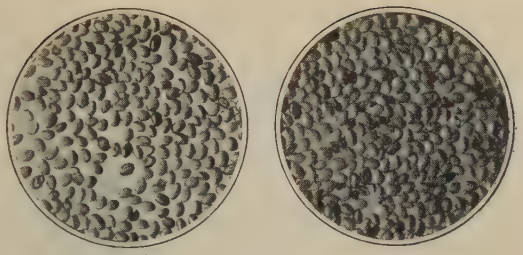


Fig. 128. — Samples of crimson-clover seed

The left-hand sample has the larger proportion of good seeds.

Japan clover is an annual legume; and where given a chance, it will propagate itself from year to year by reseeding the soil. When sown by man 10 to 15 pounds of seed are sown per acre. The spring is the best time to sow the seed. Japan clover requires a reasonably long warm season for its growth. This is the reason why it thrives in the South. It is a plant almost free from insect and fungous enemies.

Fig. 129. — Lespedeza

This legume grows fairly upright when the stand is reasonably thick.

Lespedeza provides good pasturage for horses, cattle, sheep, and hogs. It may also be used as a hay crop. Its feeding value is similar to that of the other clovers, and it stores nitrogen in the soil excellently.

Sweet Clover

Importance. — Sweet clover, once considered a noxious weed, is coming into common use for the following advantages that it

Fig. 130. — Sweet clover

This plant, not long ago considered a harmful weed, is now much cultivated as a soil builder, a pasture plant, and a forage plant.

possesses: (1) It will grow on almost any type of soil. (2) It produces a lot of excellent feed. At the Utah Station sweet

clover yielded 7700 pounds per acre, when alfalfa, timothy, and alsike clover produced 2860, 2340, and 3560 pounds respectively. (3) It is well liked by sheep, swine, horses, and cattle after they become accustomed to it. (4) It is a good preparatory crop for alfalfa, for it opens up the soil; and if the sweet clover was inoculated, it provides in abundance the bacteria essential for alfalfa production. (5) As an improver of the soil, sweet clover has hardly an equal. Fig. 9 shows the deep-penetrating root characteristics of the plant and the abundance of the nodules formed by free-nitrogen-gathering bacteria. (6) It is a biennial and needs to be resown only every two years. This is an advantage over many other crops that have to be sown or planted yearly.

Culture. — Sweet clover does best on a limestone soil — well compacted when sown. Liming the soil for sweet clover never harms its growth and usually improves it. It likes lime so well that it will grow in pure crushed limestone. Proper inoculation is absolutely essential for its best production. It is generally sown in the spring and from 20 to 25 pounds of seeds are sown per acre.

Value as a feed. — At the Wyoming Station the following results with lambs were secured with various feeds:

Sweet Clover for Lambs

	Number	Ration	Cost of Feed per 100-Pound Gain
Lot I	40	Alfalfa hay and corn	$4.26
Lot II	40	Native hay, oats, and oil meal . .	6.63
Lot III	40	Alfalfa hay and corn	4.01
Lot IV	40	Sweet clover, hay, corn, and oil meal	4.93

The Bulletin states that Lot IV in 14 weeks made a 30.7-pound gain and that Lot III, fed alfalfa, made a 34.4-pound gain in the

same time. The lambs liked sweet-clover hay and showed a steady appetite for it.

Sweet clover makes an excellent hog feed. In this respect sweet clover compares well with red clover and alfalfa (Fig. 124).

That sweet clover thrives on so many soils on which other valuable plants will not grow, that it is a superior soil builder,

Courtesy of Illinois Experiment Station

Fig. 131. — Yearling heifers in sweet-clover pasture

and that it is such an excellent feed and yielder insure it a more extensive use in the future.

Summary. — White clover and alsike are both perennials. They are excellent pasture crops. Crimson clover and Lespedeza are annuals, and sweet clover is a biennial. Each of these clovers is adapted to different soil conditions and like other legumes stores nitrogen in the soil. As feeds they are nitrogenous and hence supplement the grasses in a most satisfactory way. All of these clovers are rich in lime, while the grasses are lacking in this

ingredient; hence, in this respect, they help to balance the ration when grass is fed. In vitamins too they stand fairly high, and here again they help in nutrition.

LABORATORY EXERCISES AND HOME PROJECTS

1. Identify, draw, and describe (1) white-clover seed, (2) alsike-clover seed, (3) crimson-clover seed, (4) Lespedeza seed, and (5) sweet-clover seed.

2. Make a survey similar to the one described on p. 259 for the five plants treated in this chapter.

CHAPTER XXI

COWPEAS

History. — The cowpea is native to southeastern Asia. China and India deserve the credit for the origin and improvement of this important legume. Cowpeas were introduced into the West Indies in the early part of the 18th century and were well known in the Carolinas in 1775. Virginia grew them by 1795, and they were soon in general use, especially in the Southern States.

Courtesy of U. S. Department of Agriculture

Fig. 132. — Cowpea plant

The cowpea is more like a bean than a pea, having large, broad leaves and long, slender pods (Fig. 132). Its great value as a forage crop and its ability as a soil improver have given it an important and secure foothold on many farms in the southern and central sections of the United States.

Culture and importance of cowpeas. — In the section where cotton is grown the cowpea is the most important of the legume crops. Cowpeas are used as a forage and hay crop and, to some extent, as a human food.

Cowpeas are planted or sown about two weeks after corn-plant-

ing time and up to within 90 days of the first killing frost. A well-prepared seed bed is essential to best results in the production of the crop. When the crop is wanted for hay, the seed is usually broadcasted. If a seed crop is wanted, it is usually sown with a grain drill far enough apart so that cultivation may be practiced. The seeds should be covered from $1\frac{1}{2}$ to 2 inches deep. The rate of seeding for a hay crop is from 4 to 8 pecks, and for a seed crop from 3 to 4 pecks.

Advantages of growing cowpeas. — The cowpea will grow in almost any kind of mellow, well-drained soil, and as a soil builder it has few equals. It is a typical legume, gathering nitrogen from the air and fixing the nitrogen in the soil through the action of bacteria in its roots (Fig. 20).

Cowpeas produce either a good hay or seed crop. From $1\frac{1}{2}$ to 2 tons of good hay or from 8 to 12 bushels of seed may be expected under usual conditions and seasons.

Cowpeas are very rich, in comparison to other plants, in protein and carbohydrates. The following table gives a fair comparison:

Digestible Components of Cowpeas and a Few Other Crops

	Total Dry Matter (Per cent)	Protein (Per cent)	Carbohydrates (Per cent)	Fat (Per cent)	Nutritive Ratio
Cowpeas (grain) .	88.4	19.4	54.5	1.1	1 : 2.9
Corn (grain) . .	89.5	7.5	67.8	4.6	1 : 10.4
Cowpea hay . .	90.3	13.1	33.7	1.0	1 : 2.7
Alfalfa hay . .	91.4	10.6	39.0	0.9	1 : 3.9

Cowpea hay and cowpeas have a relatively high percentage of protein; and since the nutritive ratio of these feeds is narrow, they are highly desirable as supplements to carbohydrate feeds.

Factors aiding in increasing the yields of cowpeas. — (1) All the ordinary factors, such as season, culture, and harvesting, are important in increasing the yields of cowpeas. (2) Using the varieties adapted to the purpose for which they are grown and to the locality and soil conditions is essential for the best results.

Courtesy of U. S. Department of Agriculture

Fig. 133. — Comparative yield of iron and black cowpeas

This experiment was made on wilt-infected land in South Carolina.

Cowpea varieties have different characteristics as to time of maturity, length of stem, leafiness, and amount of seed. The following table gives a brief summary of some of these characteristics for a few leading varieties:

Variety	Color of Seeds	Days Required to Mature	Regarding Vining	Purposes
New Era	Reddish brown	110–115	Little	Seed
Clay	Tan-colored	120–125	Light in forage	Medium seed and vegetation
Early Blackeye	White with black eye	115–120		Seed and some forage
Taylor	Tan mottled with gray	110–115	Light in forage	Seed and some forage
Warren	Dark tan	110–115	Vines more	Forage
Whippoorwill	Dark brown and light spots and streaks	115–120	Great viner	Better for vegetation, hay, etc.
Red Ripper	Reddish brick-colored	110–115	Vines more	Forage

The time of harvesting depends upon the purpose for which they are to be used. The best time to cut for hay is when the seeds are well formed, some of the pods are ripe, and the lower leaves have begun to turn yellow. Harvesting at this stage of maturity gives the greatest amount of nutrients in the most digestible form.

Composition of Cowpea Hay Harvested at Different Stages of Maturity (Air Dry)

Stage of Development	Protein (Per cent)	Fat (Per cent)	Fiber (Per cent)	Nitrogen-free Extract (Per cent)	Ash (Per cent)
Full bloom . .	17.86	4.04	18.39	52.28	7.43
Pods forming . .	19.13	3.06	18.52	50.58	7.91
Pods formed . .	21.38	5.01	29.05	32.59	11.97

We note from the table that in every constituent the percentage composition is higher when pods were formed than at any earlier time.

The leaves should be carefully guarded and harvested, for they contain about twice as much protein as do the stems. The Michigan Station found the following composition of leaves, stems, and roots.

Composition of the Parts of Cowpea Plants

	Dry Matter (Per cent)	Protein (Per cent)	Nitrogen (Per cent)	Ash (Per cent)	Phosphoric Acid (Per cent)	Potash (Per cent)
Leaves .	36	27.08	4.33	16.38	0.71	1.63
Stems .	36	17.83	2.87	12.40	0.65	3.32
Roots .	28	5.61	0.89	5.38	0.62	1.32

After cowpeas are cut and slightly cured, they may be put into small haycocks and there left to cure until the stems are suffi-

ciently dry to prevent spoiling in the haymow or in the stack. One thing to guard against in haying is to prevent the leaves from matting together. In damp weather cowpeas often mildew, but mildewed cowpea hay will not harm stock, and they will eat it — although its feeding value is somewhat reduced.

If cowpeas are harvested for seed, they are left to mature. The hand and the huller method are used in separating the seed.

Barnyard manures, commercial fertilizers, lime where the soil is sour — although cowpeas will grow in acid soil — and the rotation of crops are all essential in the production of cowpeas.

Uses of cowpeas. — The seeds of cowpeas are so extraordinarily nutritious that the countries of the Old World use them for human food. Beans of various kinds are substitutes used in the United States. Cowpeas furnish nitrogenous nutrients to a larger extent than the usual food. Their nutritive ratio is as 1 : 2.9, whereas a workingman requires food that has a nutritive ratio of about 1 : 8 or 1 : 9. Therefore, cowpeas must be supplemented with carbonaceous foods in order to balance the ration properly. Although cowpeas are used to some extent in the United States, their use for human food will probably increase.

Comparison of Cowpea Hay with Timothy Hay for Wintering Yearling Steers

(104 days — Four steers in each lot — Four pounds of corn per day per steer)

	Corn Eaten (Pounds)	Hay Eaten (Pounds)	Total Gain (Pounds)	Average Daily Gain (Pounds)	Grain per Pound Gain
Corn and timothy hay .	1568	6536	260	0.64	6.00
Corn and cowpea hay .	1568	7757	624	1.54	2.51

The steers fed corn and timothy hay did 41 per cent as well as those fed corn and cowpea hay.

Cowpeas with corn as a feed have brought the following returns in pork production at the Missouri Station:

RESULTS WITH CORN AND COWPEA FORAGE

YEAR	NUMBER DAYS PASTURED	NUMBER HOGS PER ACRE	POUNDS GAIN PER ACRE	POUNDS GAIN ACCREDITED FORAGE	VALUE OF FORAGE PER ACRE. PORK @ 6¢ PER POUND
1909	30	10	568	568	$34.08
1910	57	12	276	276	16.56
1911	28	10	140	140	8.40
1912	24	24	314	314	18.84
Average .	34¾	14	324.5	324.5	$19.47

The results were obtained by hogging down corn and cowpeas. Besides the return in production of pork, the practice of "hogging down corn and cowpeas" is a simple and effective means of preparing the field for tillage and of adding to its fertility.

Summary. — The cowpea, originated and developed by China and India, is an important agricultural contribution to the world. It is important because as a soil builder and as a nitrogenous feed it has few equals. The factors that help to increase the yield and usefulness of cowpeas are proper culture, use of the variety suited to the local conditions, harvesting at the proper time, and the use of barnyard manures and fertilizers. Cowpeas are used for human food and as a hay and forage crop. Cowpea hay is scarcely excelled by any other hay.

LABORATORY EXERCISES AND HOME PROJECTS

1. Find the number of acres of cowpeas and soy beans produced in your school district.

2. Draw the seeds of three or four varieties of cowpeas grown in your locality.

3. Write three paragraphs on the advantages to be derived from the growing of cowpeas.

4. If 40 acres of cowpeas are planted and the yield is 10.6 bushels per acre, what is the money value if they sell for $1.80 per bushel? There are 60 pounds in a bushel of cowpeas. What is a pound worth at the above rate?

CHAPTER XXII

SOY BEANS

Origin of the soy bean. — Soy beans are native to southern Asia and were cultivated and improved by the Chinese centuries ago. They have been grown in Europe for about a hundred years, but they were not extensively cultivated in the United States until about 1900.

Importance of soy beans. — Soy beans do not occupy a large acreage at the present time, but the crop is increasing in popularity. Soy beans grow farther north than do cowpeas, and they promise to become one of the leading legume crops of the Middle and Northern states. As a pasture, hay, and seed crop and as a soil renovator soy beans have few superiors.

The soy-bean plant. — Soy beans resemble garden peas. They grow erect with a branching, bushy, hairy stem, which is often three and one-half feet in height. The leaves are trifoliate, about two thirds as wide as they are long. The flowers are white, pink, and sometimes purple. The pods are short, containing from 1 to 3 oval-shaped, almost round seeds. There are seldom more than three seeds in a pod. The roots are composed of a main taproot and a few lateral roots, on which are found free-nitrogen-gathering nodules.

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: a soy bean plant, showing nodules; the seeds of three or four varieties of soy beans.

Utility of soy beans. — Special advantages that may be derived from the cultivation of soy beans are the following: (1) Because soy beans grow erect, they are more easily cultivated and harvested. (2) Soy beans are not so easily injured by frosts as cowpeas and therefore may be grown farther north. (3) Because the

Fig. 134. — A fine stand of soy beans

A crop of soy beans fed to live stock and returned to the soil as manure or a crop plowed under as a green manure adds a large amount of humus to the soil.

different varieties of soy beans mature in different lengths of time, from 75 to 165 days, they may be grown from the Canadian country to the Gulf of Mexico. (4) Soy beans yield a large quantity of good seed, sometimes from 12 to 18 bushels to the acre. (5) Soy beans store as much nitrogen in the soil in as short a time as any other crop and store up more protein in the plant than cowpeas. (6) When soy beans and corn are planted together and hogged down, soy beans last longer than cowpeas be-

cause they are harder and their pods do not break open so readily. (7) The parts of the soy bean seeds are held tightly together so that they can be threshed without splitting and shattering as much as do cowpeas.

Varieties of soy beans. — Soy beans vary in size, the amount of seed produced, and the time required for maturity. The smaller varieties mature in about 75 to 95 days. They produce less growth and mature earlier. The medium-sized varieties mature in 95 to 110 days. The large and late-maturing varieties require from 120 to 165 days. The characteristics of a few varieties are here itemized:

Description of a Few Varieties of Soy Beans

Variety	Days for Maturity	Height (Inches)	Characters
Ito San	110–115	25–30	Produces average amount of seed and hay
Hollybrook	125–130	30–38	Good for forage and seed production
Mikado	130–135	30–35	Is a heavy seed producer, medium in foliage
Dwarf Brown	90	15–18	Small, scant foliage, and little seed
Mammoth Yellow	150	35–38	Foliage abundant, medium in seed

There are more than two hundred varieties of soy beans in the United States. Your Experiment Station can furnish information about the ones adaptable to your locality.

Culture of soy beans. — Soy beans should be planted in well-prepared, firm, warm soil. In the Corn Belt it is best to plant soy beans just after corn, preferably from the latter part of May to the middle of June. However, under very favorable conditions

they may be planted up to the middle of July and still produce a fairly good crop. The methods of planting and the amount of seed sown vary If the crop is to be cultivated for seed, soy beans should be planted about 2½ to 3 feet apart. If forage or hay is wanted, the seed may be drilled so that the rows will be from 12 to 18 inches apart. The method of planting 2 to 4 soy-bean seeds in each hill of corn when the corn is being planted is growing in popularity, since it does not decrease the corn yield much and at the same time does increase the soil fertility and produce more well-balanced feed. The amount of seed sown varies, of course, with the size of the seed and the purpose. If soy beans are grown for seed, about 2 to 4 pecks will be enough to sow; but if grown for forage or hay, from 3 to 5 pecks should be sown. If the seed is broadcasted, more is needed. Broadcasting is not advisable, however.

Courtesy of International Harvester Co.

Fig. 135. — Nodules on the roots of a soy-bean plant

Soil inoculation with the proper bacteria is desirable in fields where soy beans have never grown. The Department of Agriculture of the University of Missouri recommends the following: "A gallon of soil taken from among the roots of an inoculated

crop should be mixed in and drilled with every bushel of seed. This method of inoculation is simple, safe, and sure. When a field is once properly inoculated, soil from it may be used for inoculating other fields where soy beans are sown."

The methods of harvesting are similar to those used with other legume crops. If harvested for seed, soy beans should be cut when the pods begin to ripen. If the crop is allowed to mature too much, many of the seeds are lost from splitting and shattering. A regular bean huller is most satisfactory for threshing, but the common threshing machine may be used if the cylinder is run at half-speed by putting on a larger pulley and the rest of the machine is run at normal speed. Most of the concave teeth should first be removed from the thresher.

When soy beans are harvested for hay, they should be cut after the pods are about half-developed. If cut much later, many of the leaves are lost, and the stems become so woody that their feeding value is greatly reduced. In order to save the leaves which form the most valuable part of the hay, the crop must be handled in a semicured condition, put in cocks, and permitted to cure a day or two more, and then it should be permanently stored.

Soy-bean hay contains about eleven times as much digestible protein as corn silage (p. 254). Therefore soy beans and corn silage make a well-balanced ration.

Soy beans have also been used as a silage crop very satisfactorily. Two parts of corn and one of soy beans produce a silage that makes an almost ideal ration for dairy cattle, growing cattle, or sheep, because it contains proteins, carbohydrates, and fats in about the proper porportion.

Uses of soy beans. — Soy beans are almost equal in feeding value to cottonseed meal, gluten meal, or low-grade tankage. As a soil builder and a green-manure crop, soy beans have scarcely

an equal. They may also be used to advantage for seed production. In China and Japan soy beans are extensively used as household food as a balance to the rice diet.

Summary. — Soy beans are a native of Asia, and not until recently has their value been realized in the United States. They belong to the legumes and possess all their advantages. Soy beans are easily grown, contain a large amount of protein, and aid in balancing carbonaceous rations. They are fed to cattle, sheep, and swine with good results.

LABORATORY EXERCISES AND HOME PROJECTS

1. Soy-bean plants should be brought to class for study. They should be carefully described in a written composition.

2. Secure the seeds of three or four varieties and carefully examine and draw them in your notebook.

3. Have pupils tell how soy beans are planted, harvested, and fed upon any farm from which they may be able to get the information.

4. How many pounds of digestible protein are produced on an acre if 1.5 tons of soy-bean hay is made? How much digestible protein is contained in a ton and a half of corn silage? Compare a ton of silage and a ton of soy-bean hay in a written paragraph. (See p. 254.)

5. If soy beans produce 15 bushels per acre, how many bushels can be produced on 12.7 acres? What are these worth at $2.85 per bushel?

CHAPTER XXIII

ALFALFA

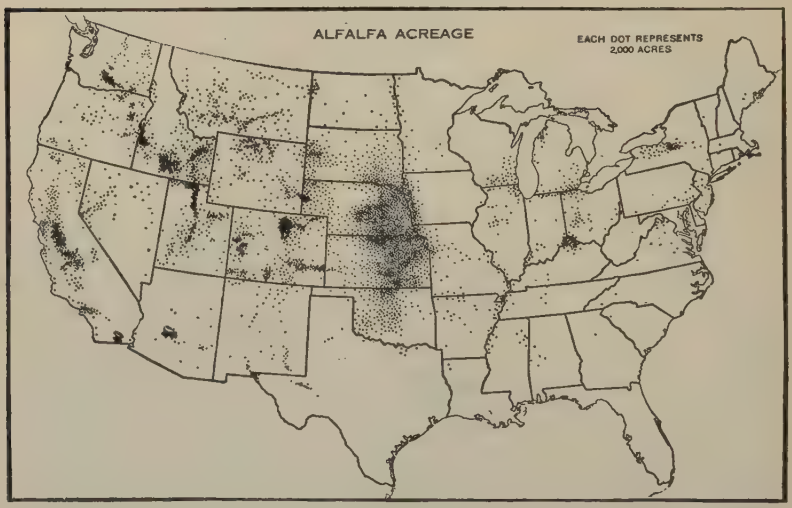
History of alfalfa. — Alfalfa is among the oldest of forage plants. It originated in central Asia. The Persians carried alfalfa to Greece in 490 B.C., and the Romans carried it to Rome in 146 B.C. It was probably carried to Spain by the Moors in 711 A.D., and from there it spread to all Europe. The Spanish introduced alfalfa into the New World. Cortez took it with him into Mexico, and it was introduced into California about 1854. Now its distribution is world-wide.

Fig. 136. — Alfalfa plants

Importance of alfalfa. — According to the 1920 Census Report there were 8,629,111 acres of alfalfa in the United States, and the total yield was 18,864,033 tons. The average yield per acre was 2.18 tons. The leading alfalfa states are Kansas, California,

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: pint samples of alfalfa seeds.

Nebraska, Colorado, and Idaho. Each of these states produces over $1\frac{1}{2}$ million tons, and besides these there are seven other states which produce from 500,000 to 1,000,000 tons each. Alfalfa states are mostly west of the Mississippi River. The



Courtesy of U. S. Department of Agriculture

Fig. 137. — Where alfalfa grows

acreage doubled during the decade 1899–1909 and nearly doubled again during the decade 1909–1919.

The map (Fig. 137) shows the distribution of alfalfa acreage of the United States, according to the Census of 1920:

Alfalfa is important because it produces more feed per acre than any other hay crop. At the Wisconsin Station it has been found that alfalfa may yield 5.4 tons per acre; red clover, 2.3; and brome grass, 1.3. Although these are higher yields than can be expected under ordinary conditions, still the comparisons are accurate.

In the table on p. 288 the digestible crude protein from several crops per acre is given.

The importance of alfalfa lies in the fact of its wide adaptability, the total yields it gives, and the large amount of protein and lime it produces (Fig. 139).

Reasons for alfalfa failures. — Failure of an alfalfa crop may be caused by one or more of the following conditions: (1) wet, impervious soils; (2) sour, acid soils; (3) lack of seed-bed preparation; (4) lack of the bacteria which aid growth; (5) overcrowding weeds; (6) cutting alfalfa too late in autumn; (7) close grazing, which soon kills alfalfa.

Factors aiding increased yields of alfalfa. — (1) *The soil.* — The kind of soil upon which alfalfa is grown is the first essential to successful alfalfa production. Rich bottom loams comprised of soils made of clays, silt, and sand are best suited to alfalfa growing. The soil must be fertile, mellow, and friable, and in first-class mechanical condition, and must have plenty of humus and some lime.

Alfalfa is sensitive to an acid or sour soil and will not grow in such a soil until the acidity is corrected by the addition of lime.

(2) *A good seed bed.* — The seed bed should be mellow, but firm, and free from weed seeds. Plowing and preparing the soil 6 or 8 weeks in advance of seeding and cultivating it about a week after each rain prepare the soil by giving the bacteria a longer time to make plant foods available and by destroying weed seeds. If the seed bed does not contain the bacteria which are essential to its growth, then the soil should be inoculated. The soil may be inoculated by scattering from 300 to 500 pounds to the acre of soil from a field where alfalfa or sweet clover has been growing.

L. E. Call, agronomist of the Kansas Station, says relative to the inoculation of alfalfa: "The soil method of inoculation is the

surest, safest, and generally the best method of inoculation. An old field of alfalfa or sweet clover that is well set with nodules should be found. The surface inch should be scooped off and the next four or five inches of soil taken for inoculating purposes. The soil should be broadcasted without drying as soon as pos-

Courtesy of International Harvester Co.

Fig. 138. — Experiment in soil treatment for alfalfa

sible over the field to be inoculated. The work should be done on a cloudy day if possible, and the soil harrowed in immediately after it is scattered."

(3) *The right kind of seed.* — Although about 90 per cent of the alfalfa grown in the United States is of the American varieties, farmers are sifting out the varieties of alfalfa and are growing those that are most prolific. There are about a dozen fairly well-

defined varieties of alfalfa, among which the following are recommended by the United States Department of Agriculture: the Grimm, the Baltic, the Canadian Variegated, and Sand Lucern.

Farmers should write to their State Experiment Station for information as to what variety of alfalfa is best adapted to their state and immediate locality.

Home-grown seed as a rule should be sown, for it usually does best. However, if superior varieties can be secured elsewhere, it may be profitable to use them.

(4) *When and how to sow alfalfa.* — The time of seeding varies with the soil conditions and season, but in many places June, July, or August is a good time for seeding.

Sometimes early-spring sowing is preferred. But fall sowing has the advantage that the alfalfa gets a start of the weeds. Fifteen to twenty pounds of seed are sown per acre. There are about 220,000 seeds in a pound and 60 pounds to the bushel. Twenty pounds of alfalfa seed evenly distributed over an acre (43,560 square feet) scatters about 100 seeds per square foot.

The depth of seeding varies according to the soil and season conditions, but ordinarily alfalfa seed is sown from one half to one and a half inches deep.

(5) *Cultivating alfalfa.* — The life period of alfalfa ranges from three to six years ordinarily. However, under good care sometimes it has grown for twenty-five or more years. Weeds are alfalfa's worst enemy. The disk harrow has been recommended as the best tool to eliminate weeds from alfalfa, but the old theory that "you can't scratch the back of alfalfa too hard" is passing, because it is possible to treat the plants too roughly. It is for this reason that the spring-toothed harrow and the ordinary spike-toothed harrow are now recommended for cultivating this crop. The grasses and weeds must be kept out of alfalfa if it is to have

a long life. Proper cultivation prevents the necessity of plowing up alfalfa fields and therefore cheapens its production.

(6) *Manures for alfalfa.* — The effect of barnyard manure upon alfalfa production is shown in the following data from the Kansas Station:

Effect of Barnyard Manure on Alfalfa Yield per Acre

	1911	1912	1913	1914	1915	1916	1917
Manure, 2½ tons annually	3659	1620	3041	4342	11110	9027	7391
No treatment	2463	920	1901	2330	5570	5307	5116

	1918	1919	1920	1921	1922	1923	Average
Manure, 2½ tons annually	3400	8373	4187	4370	2886	1606	4924
No treatment	2330	5588	2952	2940	1090	519	3002

In Iowa Experiment Station Bulletin No. 137 we read: "Eight to twelve tons per acre of good manure should be applied before plowing for alfalfa, for the use of manure is by far the most important factor in securing successful results on Iowa soils. It is a notable fact that of twenty-three correspondents who make special mention of the fact that they have manured their fields before plowing but one failed. While good stands and yields of alfalfa have been secured on fertile soils without manure, yet yields are in almost every case largely increased by its use. On soils of only medium fertility manure is essential to the greatest success; on soils below the average successful stands are practically never secured without its liberal use."

(7) *Harvesting and curing alfalfa.* — Alfalfa should be cut when the new shoots from the crown are about an inch long. It should be cut at this time even if the crop is small. Much more is lost in

the subsequent crops than will be gained in the first crop by waiting, for the new stems or shoots will be cut off and the next crop will be seriously handicapped. In the fall it is advisable to allow considerable growth as a winter covering from the cold.

The leaves of alfalfa contain about 75 per cent of the protein

Courtesy of International Harvester Co.

Fig. 139. — A ton of alfalfa hay contains 100 pounds of lime

and almost as large a per cent of nitrogen-free extract and fat. For this reason after the alfalfa is cut and has dried to some extent it should be put into cocks before it gets so dry that the leaves will be lost. After it has dried in the cocks for about a day, it should be stacked or stored in a barn. Alfalfa as a forage crop for swine has a great growing and feeding value. There is perhaps no forage crop which will produce so much pork per acre as will alfalfa, since this crop is high in mineral matter and in protein. It is therefore not necessary to feed any grain in addition to corn

when swine are fed on alfalfa forage. In pasturing alfalfa, care should be taken not to pasture too closely as the crop does not seem to be able to stand heavy foraging.

Returns of alfalfa. — Alfalfa yields well in total quantity of feed or hay produced per acre and also in the total nutrients contained in the hay harvested. The reasons why it produces so well is that the roots of alfalfa are very deep feeders, thus being exposed to much plant food and soil moisture (Figs. 31, 136).

Average Returns per Acre of Alfalfa and Other Farm Crops

	Yield per Acre (Pounds)	Digestible Crude Protein (Pounds)	Total Digestible Nutrients (Pounds)	Net Energy (Therms)
Alfalfa hay	4372	463	2250	1497
Clover hay	2624	199	1336	1015
Timothy hay	2340	70	1134	1007
Corn (ears and stover)	3574	150	2251	1961

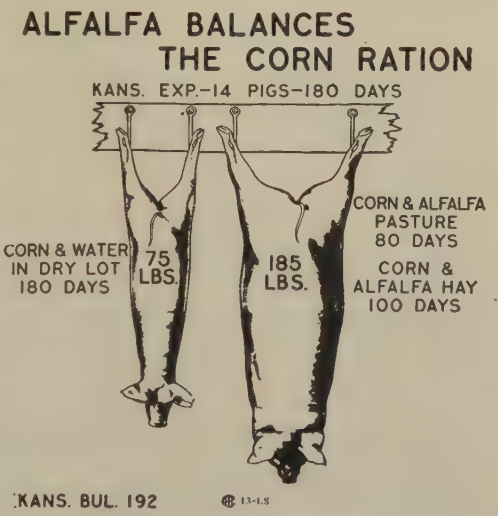
A thorough study of the figures of this table will reveal many arguments for alfalfa, for it is a splendid producer of the necessary food ingredients.

Digestible Nutrients of Alfalfa Hay and Bran

	Total Dry Matter (Per cent)	Crude Protein (Per cent)	Carbo-hydrates (Per cent)	Fat (Per cent)	Total (Per cent)	Nutritive Ratio
Corn for comparison	89.5	7.5	67.8	4.6	85.7	1:10.4
Alfalfa hay	91.4	10.6	39.0	0.9	51.6	1:3.9
Bran	89.9	12.5	41.6	3.0	60.9	1:3.9

It will be noted that alfalfa and bran have about the same digestible nutrients, and that the nutritive ratio is the same.

Alfalfa proved superior to bran in an experiment conducted by the Illinois Station. Bulletin No. 146 gives us the following data: There were six cows in the experiment — three in each lot. All of these cows freshened in December. The experiment lasted 18 weeks — divided into two equal periods. All feed given was the same in amount throughout the experiment. Everything was the same except one lot of cows was fed bran the first nine weeks and alfalfa the other nine weeks. The other lot was fed alfalfa the first nine weeks and bran the last nine weeks. The results of the experiment were that the milk produced by Lot II, fed on bran until changed to alfalfa, at once rose above Lot I and remained above. The total milk produced in favor of alfalfa, for the 18 weeks, was 375 pounds. Alfalfa is practically equal to bran as a feed for milk production.



Courtesy of International Harvester Co.

Fig. 140

Uses of alfalfa. — Alfalfa is an excellent pasture and soiling crop, but it is best suited for a hay crop. As a feed for hogs, beef cattle, dairy cattle, and sheep alfalfa among all the hay crops is unexcelled.

The two animals of Fig. 140 are worthy of study; each represents a lot of 7 pigs. Lot I was fed corn alone in a dry lot

for 180 days. Lot II was fed corn and had access to an alfalfa pasture for 80 days and then was fed corn and alfalfa hay for 100 days. The pigs in Lot II averaged 185 pounds at the expiration of 180 days, but those in Lot I weighed an average of only 75 pounds. The pigs of Lot I made gains at a cost of $31.49 per hundredweight, while those of Lot II made a 100-pound gain at a cost of $6.68. The 14 thigh bones of the hogs fed upon corn and alfalfa had an average breaking strength of 1370 pounds; while the 14 thigh bones of the hogs of Lot I, fed corn alone, had an average breaking strength of 570 pounds.

The experiment shows the relation of a balanced ration to economical pork production. Corn alone is not a good ration for either growing or fattening swine. Corn alone does not ordinarily produce economical gains.

For beef cattle alfalfa is a very fine feed. Invariably where alfalfa and timothy are tried out in growing or fattening beef cattle, alfalfa produces the greatest and cheapest gains. This is well illustrated in the following data:

Cost and Feed to Produce One Thousand Pounds of Bee

	What Was Fed	Amount	Cost
Lot I	Prairie hay	16,760 lb.	
	Grain	3,505 lb.	$45.10
Lot II	Alfalfa	10,000 lb.	
	Grain	1,620 lb.	$28.20

It required 16,760 pounds of prairie hay and 3050 pounds of grain to produce 1000 pounds of beef; and when alfalfa was fed it took only 10,000 pounds of alfalfa hay and 1620 pounds of grain to produce 1000 pounds of beef. In other words, it took only about 60 per cent as much feed when alfalfa was substituted for prairie hay in beef production. May we suggest this question, How

may the acreage be decreased, but the total yield be maintained? The answer to this question represents a type of efficiency in which all people are interested.

For the dairy calf, the dairy cow, and milk production alfalfa stands first as a hay feed. Bran is known to all dairymen as being a good feed. Alfalfa is so similar to bran as a feed, that ordinarily we speak of 11 pounds of alfalfa as being equal to 10 pounds of bran as a dairy feed.

Summary. — Alfalfa is a native of Asia. Although it was not produced into the United States until 1854, there are now over $8\frac{1}{2}$ million acres devoted to this crop. Alfalfa thrives on a deep, porous, sweet soil. Liming and inoculating the soil are frequently essential in securing results in its production. Cutting alfalfa at the proper time is important in growing the crop and in getting the best quality of hay. As a forage crop for swine it has great growing and feeding value. With corn it balances the ration. Where alfalfa thrives, it scarcely has an equal in feed-producing capacity.

LABORATORY EXERCISES AND HOME PROJECTS

1. Find the number of acres in alfalfa in the district. All pupils may aid in the survey. Every farmer should be included in this record, even if he has no alfalfa. Record as follows:

ALFALFA SURVEY DATE TEACHER

NAMES OF FARMERS	ACRES OF LAND IN FARM	NUMBER OF ACRES IN ALFALFA	LAND, PER CENT IN ALFALFA	NUMBER OF TIMES CUT

2. Examine and draw alfalfa seeds.

3. Examine a sample of alfalfa seed to see whether it contains weed seeds. What kind of weed seeds may be found in alfalfa?

4. School children should plant some alfalfa on the school grounds. If some of it can be treated with different fertilizers, some limed, and some inoculated, the test, if carefully performed, may become of real service to the farmers of the district.

5. If alfalfa is growing in the locality, dig up some plants to find the length of the roots and also to examine the nodules on the roots. Draw them.

6. Compare bran and alfalfa hay in digestible components and price.

CHAPTER XXIV

HAY PRODUCTION

Importance of hay crops. — The leading crops of the United States in order of their value are corn, hay, cotton, and wheat. It is true that they do not always stand in this order, for this depends upon the yearly production and the price of the product.

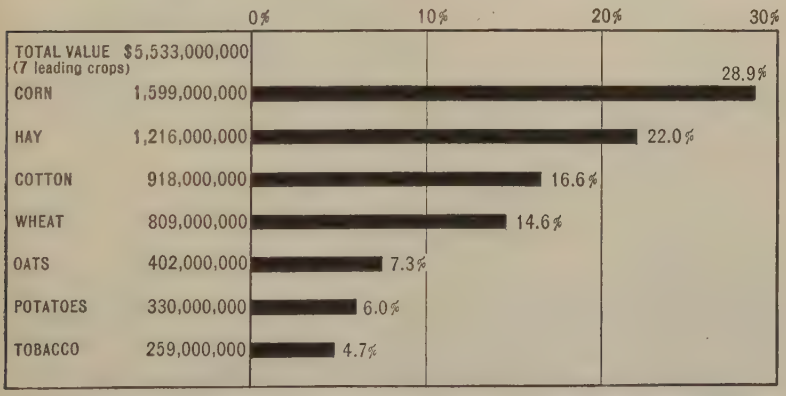


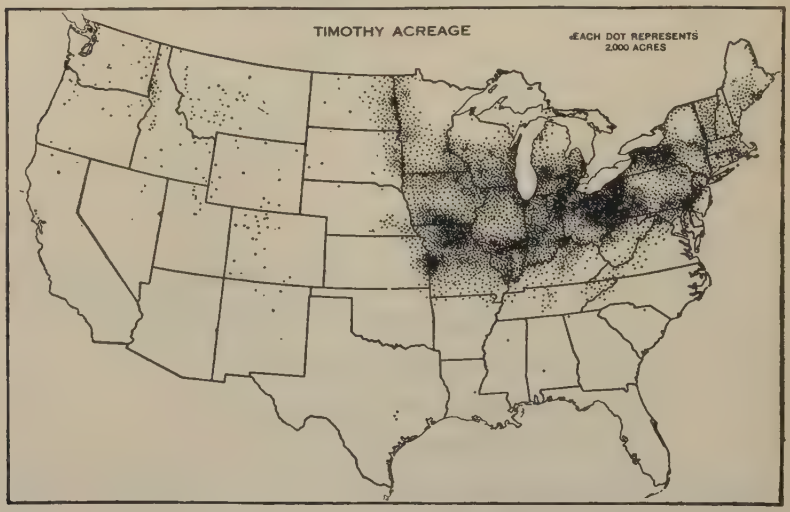
Fig. 141. — Value of leading farm crops, average 1921–1922

In 1922 the total tame hay acreage was estimated at 61,208,000 acres and the wild, salt, and prairie hay comprised 15,842,000 acres. The wild hay is produced principally in the Dakotas, Nebraska, and Minnesota.

Timothy

According to the 1920 Census Report there were 10,941,347 acres in timothy hay, and 19,349,405 acres in mixed hay, com-

prising timothy and clover hay. The timothy crop is principally grown in the northeastern quarter of the United States. The leading timothy states in the order of greatest production according to the 1920 Census were Ohio, Missouri, Illinois, Pennsylvania, New York, Iowa, and Indiana. A line extending from Minnesota to the southwestern corner of Missouri and then



Courtesy of U. S. Department of Agriculture

Fig. 142. — Where timothy grows

directly east includes the quarter of the United States that is the real timothy-producing section. The map (Fig. 142) shows the timothy acreage according to the last Census Report.

The districts of heaviest production are in eastern Ohio, western Pennsylvania, northern Missouri, and southern Illinois. These states have in general a rather heavy, slightly sour soil, which is adaptable to the growth of timothy.

The timothy-and-clover area almost coincides with the timothy area. The leading states in the production of mixed

timothy and clover hay are New York, Wisconsin, Michigan, Iowa, Pennsylvania, Ohio, Minnesota, Missouri, and Illinois. The total yield in 1919 was 25,341,786 tons, or 1.39 tons per acre. Clover is not well adapted to heavy or sour soils, and therefore this mixed hay is grown on the better types of soil.

Fig. 143. — Flower heads of timothy

Advantages of timothy. — Timothy has a few distinct and definite advantages. These advantages are: (1) When once a good stand is secured, it will grow without further seedbed preparation or cultivation for a number of years. This reduces labor and the cost of production. (2) Pure timothy hay is readily harvested for it seldom lodges and, when cut, dries out quickly. It can usually be raked and put into small haycocks the same day it is cut. (3) Timothy hay is an excellent hay for horses. Horsemen like it so well that it brings a good price in comparison with other hays. It is held in such high esteem because it is free from dust. Heaves in horses are attributed to dusty hay. (4) It is not difficult to get a stand of timothy. It is sown in the fall and the next summer the first crop of hay may be cut. (5) The aftermath of timothy makes a good pasture for a month or two. The pasturage thus afforded would probably pay the taxes on the land.

Disadvantages of timothy. — The yield per acre is not so very large, averaging only 1.17 tons; and it is not a very rich feed. The composition of a few feeds follows:

DIGESTIBLE COMPONENTS OF TIMOTHY, RED CLOVER, AND ALFALFA

	DRY MATTER (Per Cent)	CRUDE PROTEIN (Per cent)	CARBO-HYDRATES (Per Cent)	FATS (Per Cent)	NUTRITIVE RATIO
Timothy . .	88.4	3.0	42.8	1.2	1 : 15.2
Red clover . .	87.1	7.6	39.3	1.8	1 : 5.7
Alfalfa . . .	91.4	10.6	39.0	0.9	1 : 3.9

Timothy in contrast to red-clover hay has less than one half as much protein, and its nutritive ratio is 1 : 15.2, whereas the nutritive ratio of red-clover hay is 1 : 5.7. Since the nutritive-ratio requirement of horses is about 1 : 6.5, it may be seen readily that timothy is very much out of balance for a horse feed, but that clover is almost balanced in the proportion of its protein ingredients to the carbohydrates and fats.

MIXED HAYS

Advantages of a mixture of hay crops. — A mixture of timothy and red clover for a hay crop or, even better, a mixture of timothy and Mammoth clover, which matures at about the same time timothy does, has the following advantages: (1) The root systems of clover and timothy differ in their feeding habits; timothy feeds near the surface and clover penetrates deeper into the soil. The root systems utilize plant foods from different strata of the soil. (2) The food requirements of these two plants vary somewhat; therefore the two plants can secure a greater amount of plant foods from the soil. (3) The clover, being a legume, stores free nitrogen from the air in the soil. Since nitrogen makes for luxuriant growth, more timothy is produced because of the nitrogen-gathering quality of clover. (4) The feed produced is more nearly a balanced ration than timothy alone. The clover contains more nitrogen, as the above table indicates.

Culture of hay crops. — Timothy is sown in the fall, about the middle of September, on a well-prepared seed bed. If red clover is sown in timothy, it is generally sown in early spring. There are 60 pounds to a bushel of red-clover seed, and there are 18,740,000 seeds in a bushel. A bushel of seed will sow from 5 to 6 acres. When a mixture of clover and timothy are sown, 6 pounds of each to the acre should give a good stand if evenly distributed.

Fig. 144. — **Effects of fertilizers on acre yields of clover hay**

There are about 52,672,500 timothy seeds per bushel, and a bushel weighs 45 pounds.

If the land is weedy, it should be given preparation by growing two or three cleaning crops, such as corn, potatoes, or wheat. Their culture will help to eradicate the weed seeds. A fine, firm seed bed with a mellow but well-firmed subsurface is necessary to grow timothy. Neither timothy nor clover should be sown very deep. A good general rule to follow in planting seeds is to plant them at a depth of five times the diameter of the seed.

Courtesy of International Harvester Co.

Fig. 145. — Harvesting a hay crop

When meadows get thin, they may be reseeded and rejuvenated by applying barnyard manures.

Losses in yields of hay. — The loss in hay yields ranges usually from 15 to 30 per cent of the total possible yield. The cause of the greatest part of this loss is the lack of moisture. Excess of water causes losses to the extent of about 2 per cent. Plant

Fig. 146. — Stacking hay in North Dakota

diseases, insect enemies, and animal pests are charged with causing less than 1 per cent loss. Some of these losses could doubtless be prevented and will be prevented when it pays the farmer to put in the extra labor.

Making hay. — The cutting, raking, loading, stacking, and storing of hay is done mostly by machinery. The mower, the tedder, the various kinds of rakes, the hay loader, the hayfork, and the stacker all help to reduce man labor in haymaking. It

is probably safe to say that 80 per cent of the work in making hay is done by machinery (Figs. 145, 146, 147).

The time to cut hay is when it will combine the following three qualities: (1) when it will yield the most feed; (2) when it will yield the largest amounts of digestible nutrients; and (3) when it will cure so that it is most palatable.

These points have been determined by an experiment carried on at the Missouri Station from which the following data were secured:

Yield of Timothy Cut at Different Stages of Maturity

	Dry Matter (Pounds)	Crude Protein (Pounds)	Carbo-hydrates (Pounds)	Fats (Pounds)	Total Digestible Matter (Pounds)
Coming into bloom	3411	135	1676	43	1908
Full bloom	3964	147	1867	44	2113
Seed formed	4089	113	1802	51	2030
Seed in dough	4038	98	1695	54	1914
Seed ripe	3747	92	1576	38	1754

It was also found in the same experiment that where cattle had free access to the feed racks containing each of the above cuttings, they invariably chose the hay from the first three cuttings and discriminated sharply against the fourth and fifth cuttings. The palatability of timothy is greater when cut in full bloom, or about that time, than when the seeds are well formed or when the seed is ripe. No plant should be cut or stored when it is so dry that it will not pack well. Putting hay in the stack or in the haymow when it is still a little green will not harm the hay, but will improve it (Fig. 146).

Uses of hay. — Timothy hay is practically free from dust, and for that reason is preferred by some for horse feed; but as a feed it does not give as good results as some other hays. The following

data from the Kansas Station compare the value of timothy hay with the value of alfalfa hay for horses:

	Initial Weight (Pounds)	Average Gain or Loss (Pounds)	Nutritive Ratio
Lot I Corn 8 lb. Oats, 2 lb. Alfalfa hay, 10 lb.	1163	+25.6	1 : 5.8
Lot II Corn, 4 lb. Oats, 8 lb. Timothy hay, 14 lb.	1159	−7.7	1 : 9.0

In the above trial, which continued 140 days, the horses in Lot I received 16 per cent less grain and 28 per cent less hay, yet gained 25 pounds each; while the horses in Lot II lost 7.7 pounds in the feeding trial.

Fig. 147. — Baling hay

At the Illinois Station the value of timothy hay and of alfalfa hay as feed for work horses was determined. It was found that, in order to maintain the weight of the animals, less grain was required by the horses that were fed alfalfa. A saving of 22 per cent of grain in favor of alfalfa was the result of the experiment. Various experimental tests have shown that clover is a much better cow feed than timothy from the milk-production standpoint.

For sheep, timothy hay brings only fair returns. The value of timothy in contrast to clover hay as a feed for sheep is brought out in the following table worked out at the Nebraska Station:

TIMOTHY *versus* RED-CLOVER HAY FOR SHEEP

	INITIAL WEIGHT	DAILY GAIN	FEED FOR 100-POUND GAIN	
	(Pounds)	(Pounds)	GRAIN (Pounds)	HAY (Pounds)
Lot I — 90 lambs Corn 1.2 lb. Timothy hay, 1.0 lb.	64	0.19	497	547
Lot II — 90 lambs Corn, 1.1 lb. Clover hay, 1.5 lb.	59	0.32	340	475

The lambs fed corn and clover made a daily gain of 0.32 pound; and those fed corn and timothy hay gained 0.19 pound a day. The feed required to make a 100-pound gain with corn and clover was a little more than three fourths as much as the feed required when corn and timothy hay were fed. To put it another way, the lambs on the corn-timothy ration required 46 per cent more grain and 15 per cent more hay than those fed corn and clover hay.

Summary. — The hay crop of the United States ranks high in money value, and a large acreage is devoted to it. The northeastern quarter of the United States leads in hay production. A mixed-hay crop has several advantages, and therefore a larger acreage is devoted to it than to the growing of timothy hay alone. Economic production of hay is based upon scientific principles, and to feed it so that it will yield economic returns requires the further application of the scientific principles underlying feeding.

LABORATORY EXERCISES AND HOME PROJECTS

1. Get from the paper the market class and grade of three kinds of hay, and the price of each.

2. Secure the data from the United States Yearbook of Agriculture and make a graph showing the production of tame hay in the ten leading states; do the same for wild, or prairie, hay.

3. How many processes connected with hay production can you name that may be performed by machinery?

CHAPTER XXV

PASTURES

Importance of pasture crops. — Beef, pork, mutton, wool, milk, and horseflesh energy are more cheaply produced upon pasture crops than on any other feed. It costs from 20 to 50 cents per day during winter for feed per 1000 pounds of live weight, but the same product may be maintained upon pasture grasses at the rate of from two to ten cents per day. The cheapest gains on beef steers, porkers, and sheep are produced on pastures. Were it not for this fact, we would have to pay much more for our meat. Sheep production and beef production depend upon wide ranges of pastures. Wool would be much higher in price if the great states of the West did not provide so much pasture land.

Besides the regular pasture lands, other fields furnish pasture crops that can be utilized in certain seasons. The grass grown in wheat and oat fields after these crops have been harvested furnishes excellent pasture. The aftermath in meadow fields also provides an abundance of pasture. Although the stalk field can not be exactly regarded as a pasture crop, it too furnishes a great deal of feed. All these crops would be practically waste products, were they not utilized by grazing animals. All of these feeds are cheap, because little labor is expended in their production. Investigations have shown that the greatest profits in live-stock production have been made where these cheap feeds have been utilized.

Pasture plants. — The chief pasture plants are (1) blue grass, (2) white clover, (3) redtop, (4) Bermuda grass, and (5) alsike clover.

Composition of Blue Grass and Milk

	Water (Per cent)	Protein (Per cent)	Carbohydrates (Per cent)	Fat (Per cent)	Nutritive Ratio
Cow's milk	87.2	3.5	5.0	4.4	1:3.9
Blue grass	68.4	2.3	14.8	0.6	1:7.0

1. *Blue grass.* — Blue grass is the most common pasture grass in the northeastern and central parts of the United States. By its habit of growth and by its persistence it often drives out timothy, red clover, and alfalfa. It grows best in early summer and late autumn.

"Kentucky blue grass is the most important pasture grass in America. It grows best in a moist limestone, rather compact, firm soil. It grows in every section and state of our nation, but it thrives best in the regions where corn, oats, timothy, and wheat are grown. It is shallow-rooted and therefore does not do well in a dry or porous soil. Blue grass increases or reproduces by underground stems and is very hardy. Tramping and grazing seem to aid in causing this wonderful plant to yield its best results."

No single plant is superior to blue grass in its capacity to yield animal products.

2. *White clover.* — Next to blue grass and Bermuda grass, white clover is the most important pasture grass in the United States. It grows extensively from Canada to the Gulf of Mexico. White clover propagates itself from seeds and from its trailing vines. Each vining stem grows roots at the joints, from which grow new plants (Fig. 125).

White clover supplements blue grass just as red clover supplements timothy. White clover is richer in protein and helps to balance the ration for all kinds of live stock.

3. *Redtop* is well adapted to moist, acid soils and will grow in places where blue grass and white clover refuse to grow. Redtop

From Ladd's Dairy Farming Projects

Fig. 148. — A blue-grass pasture
Limestone soil produces abundant blue grass for dairy cows.

is a better pasture plant than a hay plant and ranks about third or fourth among the important perennial grasses. It is not generally sown except in soils that are too heavy, wet, or acid for timothy, red clover, or blue grass. Its feeding value as a hay is about equal to that of timothy hay.

4. *Bermuda grass* is to the Southern states what Kentucky blue grass is to the Northern states. It is adapted to almost any kind

of soil, but makes its best growth in well-drained, black-loam bottom soils. Bermuda grass provides a great deal of pasture, and should be closely grazed to get best results, as the stems get

From Ladd's Dairy Farming Projects

Fig. 149. — A good hay crop

One of the best evidences of soil fertility is heavy hay production. The aftermath of meadows is fine for pasturage.

large and fibrous when permitted to grow to any size. Bermuda hay has about the same feeding value as timothy hay.

5. *Alsike clover* is adapted to wet, even water-logged, soils. Where red clover dies on account of "clover sickness," alsike will thrive. It will grow in an acid soil where neither white nor red clover will grow. Alsike is larger than white clover. The

culture of alsike is like that of red clover. The rate of seeding is eight to twelve pounds per acre.

Pasture mixtures. — Planting a mixture of pasture grasses usually gives the best returns. A fair mixture of grass seed to sow per acre is the following:

Blue grass	6 pounds
Redtop	3 pounds
White clover	3 pounds
Alsike	1½ pounds
Red clover	3 pounds

The important advantages in growing a mixture of pasture plants are:

1. The roots of the plants feed at different depths of soil, and therefore more plant foods are exposed to their root systems.

2. The legumes gather free nitrogen from the air and store it in the soil. This makes for a more luxuriant growth of the grasses.

3. A mixture of pasture grasses matures at different seasons. Blue grass thrives in early spring and late fall. The clovers are in their glory in midsummer. Maturing at different seasons distributes the feed throughout the growing season.

4. A mixture of pasture crops helps to balance the ration, as may be seen from the following table, showing the percentages of the digestible nutrients composing the main pasture grasses:

DIGESTIBLE COMPONENTS OF PASTURE GRASSES

PLANT	DRY MATTER (Per cent)	PROTEIN (Per cent)	CARBO-HYDRATES (Per cent)	FAT (Per cent)	NUTRITIVE RATIO
Blue grass	31.6	2.3	14.8	0.6	1 : 7.0
Redtop	39.3	1.9	20.0	0.6	1 : 11.3
White clover	21.8	3.1	9.6	0.5	1 : 3.5
Alsike	21.5	2.3	10.4	0.4	1 : 4.9
Bermuda	33.2	1.4	17.0	0.5	1 : 12.9

It may be seen readily from this table that the legumes are comparatively rich in protein. White clover and alsike have fairly narrow nutritive ratios, while the grasses have wider nutritive ratios. About 60 per cent blue grass and 40 per cent white clover make an ideal ration for any live stock.

5. A mixture of plants will fit different soil conditions. Blue grass and white clover demand a fairly well-drained, sweet soil — preferably a limestone soil. Redtop and alsike will do very well in a damp or wet soil, which may be acid.

6. Different plants require different amounts of light. Blue grass does fairly well in shady places. The other pasture plants require more sunshine.

There is no single plant that will produce better yields of animal life than blue grass; but that blue grass and some legume plant will bring better, larger, and more economic returns remains unquestioned.

Temporary pastures. — *All-year pastures.* — The best farmers of our country attempt to provide green succulent feed for swine, sheep, dairy cattle, and poultry if possible every day in the year. Of course corn silage is an excellent succulent feed in summer during a shortage of grass as well as in winter.

But the pasture crops that we would refer to in this section are composed of such plants as the following: (1) rye for fall, winter, and spring; (2) oats and Canada field peas for spring and early summer; (3) rape and vetch and oats for fall; (4) rape, oats, and cowpeas in spring; (5) oats and wheat for fall; and (6) cowpeas or soy beans for summer plus the regular pasture crops.

At the University of Missouri a bushel of corn yielded on an average 66 cents' worth of pork, but with the pasture and forage crops it yielded $1.10 worth. In other words, a bushel of corn produced almost twice as many pounds of pork when it was sup-

plemented with a pasture or forage crop. In the above figures pork was sold at 6 cents per pound.

Yields of pastures. — Plants make a very long growth in one season. It is said that if four average crops of alfalfa harvested from one field could be placed above one another as they grew

Courtesy of Alabama Experiment Station

Fig. 150. — Corn with velvet beans between the rows
This combination alone or with peanuts makes fine pasturage for live stock, especially hogs.

in the field they would make a height of 12 to 15 feet. Blue grass would not reach such a height in one season, but it is very dense. It forms a veritable mat, even so thick that Dean Henry found at the Wisconsin Station that 3.7 acres of excellent blue grass pasture kept three cows for 122 days. Will 3.7 acres of any other crop keep three cows for 122 days, with as little labor as is required on a pasture?

On the use of forage crops in economic pork production the United States Department of Agriculture has given out the following valuable data:

One bushel of corn fed alone will produce 10 lb. of pork.
One bushel of corn plus blue grass will produce 12 lb. of pork.
One bushel of corn plus clover will produce 18 lb. of pork.
One bushel of corn plus rape will produce 20 lb. of pork.

From these data we may see the value of forage crops in pork production, for they almost double the pork produced with a given amount of corn.

Management of pastures. — Very little time or work is spent upon pastures. It is a common belief that pastures will do well without any care or labor. However, it may be safely stated that if farmers would spend one half as much time per acre upon their pastures as they do upon the production of corn or wheat, much better results would be secured.

Pastures are often grazed too early in the spring and too late in the autumn. Early spring grass is soft and watery and has little feeding value. Early grazing stunts the growth of the grass for the entire season. However, after the roots of the pasture plants have attained their normal size and number in the early spring, the large root surface will be conducive to a rapid, continuous, and abundant growth throughout the entire growing season even if heavily grazed. It is more economic in the management of the farm to continue feeding into the spring months. Legume hay and corn silage may be fed in early spring, or even in midsummer during a shortage of pasture grasses.

If grass plants get too large, it indicates insufficient pasturing. When the grass plants get large, the stems and leaves begin to bleach near the surface of the soil. The bleached grass is semi-dead and does not manufacture the most food when the maximum amount of green leaf surface is exposed to the sunshine. The

green chlorophyll bodies in the leaves of plants are the only true manufacturers of starch in the world. For further information read a good textbook on botany.

Pastures are often grazed when the ground is wet and soft. This is a poor practice, for tramping wet soil puddles it, and thus reduces its producing power. During such periods, when the soil is so wet that it will pack, feed corn silage and legume hay.

Weeds and shrubbery should be kept out of pastures, for they take room and rob the grass of plant foods, soil water, and sunshine. Mowing the grass a few times through the season is time well spent. If a mower is used, it should be set high enough so that the grass itself is not injured. The weeds should be cut before they grow new seeds. Sheep and goats help to renovate pastures. Hogs should not be permitted to root up pastures.

Bare spots in pastures need re-seeding, light harrowing, and a top-dressing with manure. When commercial fertilizers are used, a nitrogenous fertilizer in the form of nitrate of soda of 150 to 200 pounds per acre is recommended. Occasionally a complete fertilizer is used having the following composition: nitrogen, 4 per cent; phosphoric acid, 12 per cent; and potash, 2 per cent. About 400 pounds are used per acre. All the pasture plants do better in a sweet soil, and some of them will not grow at all in an acid soil. Ground limestone applied in amounts of one to two tons per acre will correct the acidity.

Summary. — The beef, dairy, mutton, pork, and poultry products derived from pastures are large. Blue grass, redtop, white clover, and alsike clover are our most important pasture plants. Growing a mixture of grasses and legumes has many advantages. Keeping pastures free from weeds and permitting the grass to get a good start in early summer are important in the management of pastures.

CHAPTER XXVI

POTATOES

Irish Potatoes

History. — The Irish potato is of American origin. It is native to the elevated valleys of Peru, Chile, and Mexico. Some of the wild forms of the potato have been found growing in Arizona and Colorado. Potatoes were imported into Ireland in 1586. The English colonists secured them through trade with the Spanish people. Potatoes proved valuable as a food and are now grown in practically every country of the world.

World potato production. — Agriculture must be considered more and more from an international standpoint. The food required by the population of the world must be supplied. Many nations produce all the food, clothing, and shelter they need. But some nations do not. International trade, exports and imports, and prices of agricultural products are largely determined by the agricultural products produced, and the amount used in the home country. The population of the world is estimated to be 1,748,000,000 or 30.5 persons per square mile and the average number of bushels of potatoes produced for a recent five-year period was 4,391,600,000 bushels, or 2.5 per person. Some countries produce and consume many potatoes while others use few. As the population increases, and if a high state of civilization is maintained, more potatoes will be produced and used.

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of the chapter are: samples of potatoes.

World Potato Production, 1920

Nation	Population	Potatoes Raised (Bushels)	Yield per Acre (Bushels)	Potatoes Produced per Person (Bushels)
Germany	59,858,000	1,024,301,000	171	17
Poland	30,672,000	664,920,000	164	22
France	41,476,000	427,610,000	120	10
United States	105,710,000	403,296,000	110	3.9
Czechoslovakia	13,500,000	183,810,000	123	13.6
Canada	8,788,000	133,831,000	170	15
The Netherlands	6,841,000	121,514,000	284	18
England and Wales	35,678,500	117,637,000	216	4.9
Spain	20,720,000	107,834,000	128	5
Belgium	7,684,000	82,912,000	227	11
Ireland	4,390,000	74,141,000	127	17
Sweden	5,814,000	61,639,000	168	10.6
Japan Empire	77,105,000	58,206,000	121	3.8
Italy	31,446,000	52,260,000	70	1.7
Denmark	3,283,000	45,316,000	199	12
Switzerland	3,881,000	28,256,000	230	7
Chile	3,755,000	10,377,000	136	2.7

The United States produces about 3.9 bushels of potatoes per person and uses on an average 2.5 to 2.75 bushels per person. The rest of the potatoes are used for seed potatoes and for export.

Denmark has a population of 193 people per square mile and produces 12 bushels of potatoes per person. Doubtless they consume most of these potatoes in their own country.

Potato production in the United States. — In 1922 there were produced in the United States on 4,331,000 acres 451,185,000 bushels, or an average of 104 bushels per acre, valued at $262-608,000. This was a yield considerably above the average, but the total value was exceedingly low. In 1921 there were produced 361,659,000 bushels and their value was $398,362,000.

These figures are an illustration of varying yields and values. They also illustrate that small total yields may bring more money than large yields. In fact a ten per cent overproduction usually results in very low prices.

POTATO PRODUCTION IN TEN STATES, 1923

	BUSHELS	PRODUCTION PER CAPITA (BUSHELS)
United States	412,392,000	3.9
New York	39,729,000	3.8
Minnesota	38,304,000	16.0
Michigan	35,796,000	9.7
Maine	31,992,000	41.7
Wisconsin	26,212,000	10.0
Pennsylvania	26,145,000	3.0
Idaho	14,985,000	34.7
Virginia	14,136,000	6.1
Colorado	13,530,000	14.4
North Dakota	13,114,000	20.3

The population of New York State is 10,385,227. New York State produces less than four bushels of potatoes per person; Idaho has a population of 431,866 persons and produced 14,985,000 bushels of potatoes, or 34.7 bushels per person.

Advantages of potato production. — Potatoes may be successfully grown in almost any kind of land in all the Northern latitudes and higher altitudes. Potatoes yield more food per acre than wheat and almost as much as corn.

Slightly more than four bushels of potatoes are equal in food value to one bushel of wheat. Therefore 60 or 70 bushels of potatoes are equal in food value to the average acreage wheat yield. The average acreage yield of 95.3 bushels of potatoes from 1910–1919 is a superior production.

Because potatoes contain about 80 per cent water they are not shipped long distances.

Potatoes require no special machinery such as the threshing and milling machinery needed to prepare wheat for human

Fig. 151. — Planting potatoes in Minnesota

All operations of planting, cultivating, spraying, and digging (Fig. 153) may be performed by machinery but picking up must be done by hand.

consumption. There are no technical processes needed to produce potatoes nor to get them ready for table use. The potato is ready for cooking as soon as it comes out of the ground. Potatoes are an excellent substitute for wheat in the human diet. They are a cheap and reliable feed in the production of pork. The high carbohydrate content of the potato makes it

an excellent feed for fattening swine. Potatoes are, next to wheat, the most important source of starch for human food in America; they can be prepared in many different ways; and they are relished by practically all people.

Qualities a potato should possess. — Potatoes should possess the following qualities: (1) They should be prolific yielders. (2) They should be of a good size and shape — firm, medium-sized potatoes are preferred. (3) Potatoes must possess good cooking qualities and have a good flavor. (4) Smooth potatoes having few and comparatively shallow eyes are desired by the market. (5) Resistance to disease is an important feature — some varieties and strains within the variety are more resistant to disease than others. (6) Time required for maturity is an important consideration — in some sections the early-maturing varieties are desired, in other sections the reverse quality is preferred. (7) The potato should be true to type in shape, color, peeling, and flavor. Seed potatoes should be carefully purchased and then improved from year to year by selection.

Factors aiding potato production. — Good crop yields can not be produced unless all the needs of the crop are supplied. It is not accident that produces good yields; it is the application and provision of all of the factors that are essential for production. In other words, the production of a maximum yield at a minimum cost is a science.

1. *Preparation of a good seed bed* is essential in potato culture. In the first place, a deep, loose, fertile soil is necessary for good yields and, second, fall plowing aids materially in increasing the yield.

2. *Fall plowing* has several advantages: (1) It catches and conserves more soil moisture. (2) It gives an opportunity for earlier planting. (3) It keeps down weeds. (4) It liberates more plant foods. In some instances a shallow spring plowing

is necessary to put the seed bed in good condition. The depth of plowing in the fall should be about 8 to 10 inches deep.

3. *The kind of seed used* as to quality, size, and variety affects yields. Seed potatoes should be of good quality, smooth, somewhat above the size of the average potato, and free from disease.

Fig. 152. — Effect of fertilizer on potatoes

In a test at Ogdensburg, Wisconsin, fertilizers increased the yield from 79 bushels to 248 bushels per acre.

Northern-grown seeds seem to be freer from disease than those grown in the South. Varieties of potatoes vary in their adaptability to different localities, and every locality must settle the question for itself as to what variety will do best in that immediate state and neighborhood. Early varieties mature in 70

to 90 days, and there are some varieties that continue to grow for two hundred days.

EARLY VARIETIES:
Bliss Triumph, Early Ohio, Six Weeks, Early Rose.

LATER VARIETIES:
Irish Cobbler, Early Rose (some strains), Nebraska.

LATE VARIETIES:
Irish Cobbler (some varieties), Rural New Yorker, Burbank.

At the Nebraska Station (Bulletin No. 182) in average yield during the years of 1921, 1922, and 1923, the three most prolific varieties per acre were Triumph, yielding 109.7 bushels; Irish Cobbler, 103.7 bushels; and Downing, 100.6 bushels; while the three lowest yielding varieties returned only 80.4, 88.8, and 89.3 bushels per acre respectively. Selecting adaptable and prolific varieties helps to increase potato yields and to reduce the cost of production (Fig. 55).

4. *The time and method of planting* is an important factor in potato production. No exact date can be suggested, but there is no question that early planting brings best returns. From 15 to 20 bushels of seed should be planted per acre; however, heavier planting usually produces larger yields. At the Indiana Station, Circular No. 45 states that in an experiment a variety was planted at the two rates of 14 to 15 bushels and 22 bushels per acre. The increase from the higher rate of planting was 52 bushels per acre.

Seed potatoes should be cut to an even size with one to three eyes in each piece. Cutting several days before seeding has no virtue and some evils. Potatoes should be planted from $2\frac{1}{2}$ to 4 inches deep, the rows being from 33 to 36 inches apart, and the seed planted from 12 to 15 inches apart in the row. Methods of culture and number of eyes on the seed potato

determine to a considerable extent the distance apart potatoes should be planted.

5. *Sprouting seeds* increase potato yields because the plants have from two to three weeks start over potatoes not sprouted.

Courtesy of International Harvester Co.

Fig. 153. — A potato digger in operation

This machine has greatly diminished the hand work that the potato crop demands.

Seeds that are kept in cold storage up to the time of planting do not start to grow for about ten to fifteen days. Seeds are sprouted by placing them in a warm lighted place for three or four weeks before planting. During this period the buds get a good start

but should not be permitted to get too long. The growth can be checked by placing the potatoes in a cool place.

6. *The cultivation of potatoes* resembles the cultivation of corn; therefore fall plowing is recommended because fall-plowed soils

Courtesy of International Harvester Co.

Fig. 154. — Sprouted seed potatoes

Careful planting of sprouted seed potatoes will hasten the crop.

dry out early in the spring and hence are ready for planting early, a very important factor in securing maximum yields. At the Kansas Station the following yields were secured by plowing at three different times.

When Plowed	Yield per Acre (Bushels)
March	180
July (preceding summer)	200
July and March (two breakings)	225

A second plowing is sometimes necessary because of the fact that in some seasons the soil becomes packed.

The first cultivation may be close and deep, and the later ones more shallow. Plowing once every 7 to 10 days until the vines become large is a good practice, or plowing after each rain in order to break up the crust usually brings good returns. Nearly level cultivation should be practiced, although slight ridging may be used in case the weeds can not be controlled with level culture.

Courtesy of U. S. Department of Agriculture

Fig. 155. — Potato leaf showing blight

7. *Barnyard manure* is an important factor in production. However, since manure harbors potato scab and other enemies of the potato, it is advisable to apply manure the preceding season, or elsewhere in the crop rotation. Minnesota Circular No. 38 recommends that from 8 to 10 tons of manure be used per acre, it being inadvisable to apply more than 15 tons per acre.

Control of potato diseases. — Potato blight is the most destructive potato disease. The disease is limited to the northern and northwestern sections of the United States. Blight appears usually at the blossoming period and shortens the life of the plant from two to five weeks. Since the last few weeks are the most important as far as the growth of the tubers is concerned, it is important that the blight be combated.

The potato blight is combated by the use of Bordeaux mixture. Spray should be used as soon as the blight appears and every 10 to 14 days thereafter until the potatoes are matured. The leaves of the plants must be kept green, for it is there that the starch which makes the tubers is manufactured. Getting the plants

From Watts' Vegetable Growing Projects

Fig. 156. — Potatoes from equal areas

Middle lot, unsprayed; at the left, sprayed, 71 bushels per acre; at the right, low-pressure sprinkled, 30 bushels increase per acre.

started two weeks earlier by sprouting the seeds and prolonging the green foliage two weeks through spraying are very important in securing the full growth of the tubers.

The value of spraying potatoes is well shown in the following quotation from Farmers' Bulletin No. 868: "The fact that spraying pays has been established by extensive experiments which have been conducted in New York and Vermont. During a 10-year period at different Experiment Stations in New York

State, an average gain of 60 bushels per acre was secured. At the Vermont Station, during a 20-year period, which involved all possible variations, an average gain of 105 bushels per acre, or 64 per cent, over the unsprayed yield resulted."

Potato scab is a fungous disease and is the work of soil bacteria. Planting infected seed potatoes is the chief agency in spreading the disease. An abundance of barnyard manure seems to foster the growth and multiplication of the bacteria.

Fig. 157. — Potato scab

This disease can be controlled by selection and treatment of seed and by rotation.

Potato scab may be successfully combated by soaking the seed for two hours in a solution of formalin, made by mixing one pint of 40 per cent formalin with 30 gallons of water.

Control of insects. — The loss to potatoes annually from insects and disease amounts to 100,000,000 bushels. This is about 20 per cent of the crop. The Colorado beetle, known to all potato growers, is one of the worst enemies of the potato. The bugs should be killed early, for one female lays from 1800 to 1900 eggs.

The potato beetle is easily destroyed by spraying. One pound of arsenate of lead and one pound of soap added to 25 gallons of water forms the best spray. Spraying early has many advantages: (1) The bugs are smaller and softer and hence it requires less poison to kill them. (2) The bugs are fewer. (3) The plants are smaller. It usually takes from 3 to 5 sprayings to control the beetles (Fig. 158).

From Peabody and Hunt's Biology and Human Welfare

Fig. 158. — Life history of the potato beetle

Sweet Potatoes

History. — Sweet potatoes like corn and the Irish potato are of American origin. They were found by the early settlers in South America. They are adapted to tropical conditions. Although their growth on a commercial scale in the United States is confined to the cotton-growing states, they are grown in a limited way in every state of the Union. About $4\frac{1}{2}$ months of warm weather are required to grow the crop.

Sweet-potato states. — The total yield of sweet potatoes for 1922 was 109,534,000 bushels or about one bushel per person in the United States. The following states are the leading states in their production:

Principal States Producing Sweet Potatoes

	Bushels
Alabama	13,490,000
Georgia	12,616,000
North Carolina	12,430,000
Mississippi	11,445,000
South Carolina	9,568,000

It may be seen that these five states produce about one half of all the sweet potatoes grown in the United States. The average yield per acre for the years 1913–1922 was 98.1 bushels.

Culture. — Sweet potatoes grow fairly well in almost every type of soil but do best in a sandy or sandy loam soil. Deep and thorough plowing will help materially to increase the yield. The addition of manure or commercial fertilizer will return good dividends in the growing of sweet potatoes. Sweet potatoes

Fig. 159. — Sweet-potato leaves

On left, cut-leaf type; in middle, shouldered leaf; on right, entire, or round, leaf.

should be grown in rotation with other crops. Plowing under a cover crop or green-manure crop assists in making a suitable seed bed.

The sweet potato is a biennial plant. It seldom flowers to bear seeds and hence it is propagated from the roots. The roots are put in a hotbed, where they grow numerous slips. These slips are carefully pulled off the roots and planted. It requires about 10,000 plants for an acre. Planting on ridges is commonly practiced, and the cultivation of sweet potatoes is like that of corn.

Harvesting and storing. — Sweet potatoes are dug or plowed out in the late fall, but before frost. They are stored in different ways. Where only a few are grown, they may be stored in a pit. Where grown commercially, they are stored in houses built for that purpose. Drying out the excessive moisture in the potatoes is the main purpose of storing. It requires a temperature of

Fig. 160. — Sweet-potato vine and roots

80° to 90° Fahrenheit for three or four weeks to dry them thoroughly. Stove heat is often used in drying and curing them. Ventilation is essential in curing, and hence provision is made for ventilation in the construction of storage houses.

Uses of sweet potatoes. — They are used principally as food for man, but they also are fed to animals, especially hogs, these animals doing the harvesting. Sweet potatoes are rich in starches and sugar, containing 24.2 per cent, while Irish potatoes contain

only 15.8 per cent of carbohydrates. Sweet potatoes contain 31.2 pounds of digestible matter, while Irish potatoes contain only 21.2 pounds. In other words, sweet potatoes are about $1\frac{1}{2}$ times as nutritious as are Irish potatoes.

Summary. — The Irish, or white, potato crop is one of the most important farm crops. The acreage yield of potatoes is large, and its food value exceeds that secured from an equal area of wheat. No technical processes for production and harvesting are required. They are ready for table use when dug. Kind of soil, fall plowing, variety of potatoes planted, time of planting, proper cultivation, barnyard manures, commercial fertilizers, and combating insects are important factors in securing good potato yields.

Sweet potatoes are grown especially in the Southern States but can be grown throughout the Union. They are used principally for human food. They are stored and cured in specially constructed warehouses. These storage houses are often co-operative.

LABORATORY EXERCISES AND HOME PROJECTS

1. Make a survey of the approximate white and sweet potato acreage and yields in your school district. Record results in your notebook.

2. Score Irish and sweet potatoes according to the score card found on p. 399.

3. With the help of your parents estimate in itemized statements the cost of potato production per acre. Compare the cost of potato production with the cost of wheat, corn, and oat production.

4. Provide two white potatoes. Weigh the smaller one. Peel the larger potato and pare it down until it weighs the same as the potato with the peeling on. Weigh the potatoes on alternate days for about two or three weeks. Record results. Discuss the functions of peeling, bark, and skin.

CHAPTER XXVII

PRODUCTION OF COTTON

Importance of cotton. — Cotton is one of the most important crops of the United States. With a good crop and good prices cotton brings prosperity to the entire South. Moreover, the prosperity of any section of the United States makes itself felt throughout the land. When cotton brings a good price, it provides money to the cotton growers, ginners, spinners, and weavers, and to the railroads. Much of the money thus brought to these people is used in turn to buy the foodstuffs, clothing, machinery, and other conveniences produced in other parts of the United States.

The growing, ginning, spinning, and weaving of cotton engage the full time of many workmen. Our transportation is materially increased by the cotton industry because all of the cotton grown is taken from the farm where produced, practically all of it being carried at some time or other by the railroads and about half of the entire crop is exported and carried by ships (Fig. 179).

Cotton ranks high in comparison with other crops in the United States. Refer to Fig. 60, which gives the comparative value of the leading crops for the three periods 1910–1914, 1915–1920, and 1921–1922.

The cotton plant. — The cotton plant is the most important fiber plant. The stem of the plant grows erect and ranges from about two to ten feet in height, the commercial varieties being two to five feet high. The limbs grow laterally and rather symmetrically on the main central stem. The limbs grow shorter

from the lower to the upper limbs; so the entire plant is cone-shaped. There are two kinds of limbs: vegetative and fruiting. The long limbs are vegetative, and the short ones fruiting (Fig. 166). The stem is quite woody; but after the plant is

Courtesy of International Harvester Co.

Fig. 161. — Picking cotton in Georgia

dead the stem decomposes as readily as the stem of the corn plant, and especially is this true when it is plowed under.

The cotton plant has one long root which is a continuation of the stem. The lateral roots grow within two or three inches of the surface of the ground and hence deep or close cultivation is harmful after the plants are six or eight inches tall.

The leaves are not uniform in shape; most of them are three-

lobed, although some are five-lobed. The under side of the leaves is covered with short, inconspicuous down.

The flowers are set in a cup of five petals and five united sepals, and each boll has either four or five divisions known as *locules*. The content of each division is called a *lock*. In each lock is found from six to twelve seeds (the average is nine), and in each boll there are from twenty-five to fifty seeds. The number of bolls on a plant varies from a few to several hundred, depending upon the fertility of the soil, the rainfall, and the temperature. An average field contains 10,000 plants per acre. With an average production of 10 bolls per plant each acre would yield 100,000 bolls. Since it requires 70 bolls to make a pound of seed cotton, the total yield per acre would be 1429 pounds of seed cotton. This should gin out $33\frac{1}{3}$ per cent lint, about 480 pounds, and 950 pounds of seed. The bagging and ties on the bale would weigh 20 pounds, making the total weight of the bale 500 pounds.

Fig. 162. — A cotton boll ready for picking

The fiber of lint consists of a single elongated tube. It ranges from $\frac{1}{1500}$ to $\frac{1}{1200}$ inch in diameter and varies in length in different classes and varieties of cotton. The cotton fiber is said to be three times as strong as a wool fiber of the same diameter. It is covered by an oil which prevents it from readily absorbing water. The flower buds appear when the plant is about 40 days old. These buds will bloom in about 21 days of warm weather;

and they will mature 40 to 50 days after blooming. Upon maturing, the fiber collapses and becomes twisted. On the basis of maturity as indicated by the twisting of the fiber cotton is classified into three kinds: (1) ripe, (2) partly ripe, and (3) immature. The well-matured fibers are more desirable for yarn, because a twisted thread is stronger and does not slip when woven into fabrics. Mature fibers absorb and hold dyes more readily and for that reason are more desirable also.

Duggar, in "Southern Field Crops," says, "Therefore, to secure the best grade and price, bolls of cotton should not be picked until well opened, thus giving an opportunity for sun and air to mature the fiber.

"The value of cotton fiber is determined by (1) length, (2) strength, (3) maturity, (4) fineness, and (5) uniformity. The longest fiber is usually the finest, and such fibers may be used in the manufacture of the finest, thinnest, and most expensive cotton fabrics."

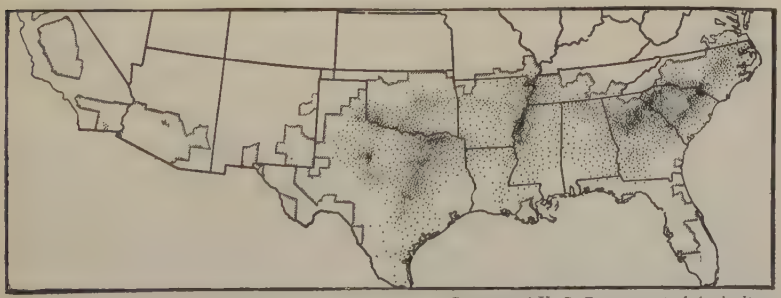
Uses of cotton. — The cotton fiber, or lint, is used in making many things. Various articles of clothing, such as underwear, overalls, jackets, stockings, and gloves are commonly made of cotton. Ginghams, unbleached muslin, fine and coarse madras, dimity, and other materials of various designs and colors are cotton fabrics. These fabrics bring from 5 or 6 cents to as much as $1 a yard. From cotton are also made sheeting, ropes, and strings. In fact from the original cotton fiber, by different methods used in spinning, weaving, finishing, and coloring, almost any fabrics demanded by the people can be made.

For every pound of fiber or lint there are approximately two pounds of seed. Cottonseed meal is made from the seeds. The hull covering the seed is taken off by machinery and the oily kernels are crushed, heated, and subjected to pressure to remove the oil. The residue is made into either cottonseed cake or meal. There

are several grades of cottonseed meal, such as choice, prime, and good. Prime cottonseed meal is the middle grade; it has total dry matter of 92.2 per cent, or 33.4 per cent of digestible crude protein, 24.3 per cent of digestible carbohydrates, and 7.9 per cent of digestible fat. The nutritive ratio is 1 : 1.3. Cottonseed meal is extensively used as a nitrogenous supplement to corn and corn silage.

A ton of cottonseed yields 69 pounds of short fibers, 579 pounds of hulls, 915 pounds of cake or meal, 279 pounds of crude oil, and 120 pounds loss, etc. The utilization of all of these by-products helps materially in making the cotton crop profitable.

The Cotton Belt. — Cotton will thrive in a wide range of soil conditions. The dark-colored clay lands, rich in lime, sandy-loam soils, and the well-drained bottom lands of many sections are well suited for large yields of cotton. Rich alluvial soils have a tendency to produce too much stalk and not a good boll. Continuous cropping has in many sections decreased yields, and more attention is constantly being given to enriching the soil and securing larger yields. The cotton-producing states are shown in the following map:



Courtesy of U. S. Department of Agriculture

Fig. 163. — Where cotton grows
Each dot represents 4000 bales.

The northern boundary of the Cotton Belt has an average summer temperature of 77 degrees. Cotton production seems to be unprofitable farther north where the temperature is cooler. The season from the last killing frost of spring to the first of autumn is about 200 days in length. It runs from about April 10 to October 25 along the northern limits of the Cotton Belt, or to November 25 in its southern part. Six or seven months of warm weather are required for the growth and maturity of cotton.

Frequent rains during the growing season are best for the growing of cotton, and during the harvesting season a rather long period of dry weather with an abundance of warm sunshine helps in producing a quality fiber with a beautiful clear white color.

History of cotton. — The early history of cotton is obscure. Some authorities believe that cotton is native to the tropical regions of both the eastern and the western continent. India was probably the first country to grow and use cotton. From India it was taken to Egypt, where it was in use more than 1000 years before Christ. From Egypt it was taken to Southern Europe.

Columbus found cotton growing in the West Indies; and Cortez, in Mexico. Central and South American countries were growing and using cotton when the earliest explorers visited them.

India was for many years the most important cotton country in the world, but at the present time the United States leads all other nations in its production and exportation. The yearly cotton production of the world averages about 19,500,000 bales. The United States produces on the average 52 per cent of this; China, 19 per cent; British India, 18 per cent; Egypt, 5 per cent; Brazil, 2 per cent; all others 4 per cent. That

there is considerable variation for any particular year is shown by the following graph:

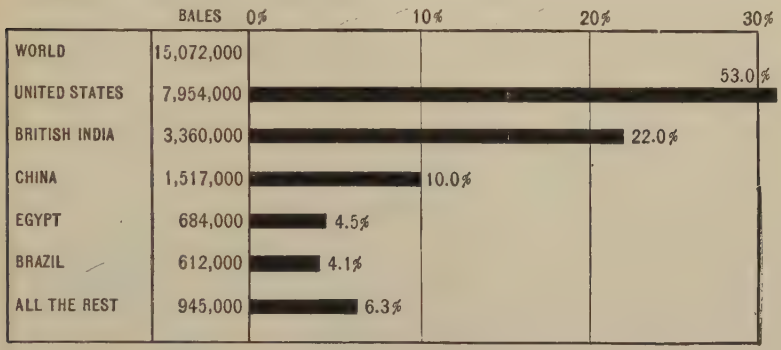


Fig. 164. — Principal cotton-producing countries, average 1921–1922

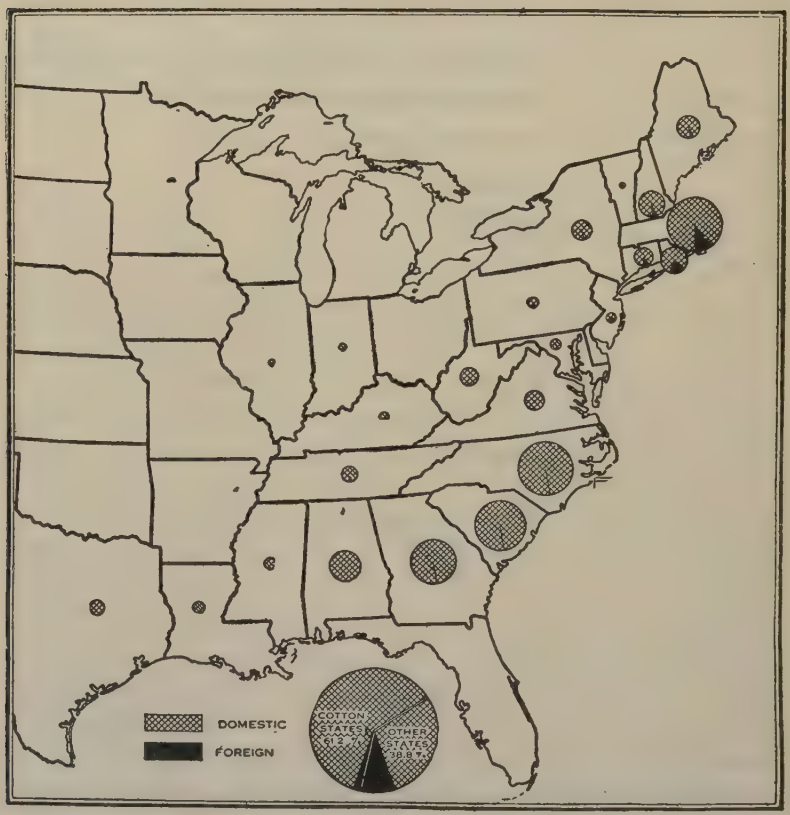
The production of cotton in the United States has steadily increased from decade to decade as the following data show:

Decade	Average Yield (Bales)
1866–1875	3,250,000
1876–1885	5,652,000
1886–1895	7,637,000
1896–1905	10,409,000
1906–1915	13,012,000
1916–1922	11,082,000

From the above data it may be seen that the total production of cotton more than doubled in the period from 1866 to 1895, and nearly doubled in the period from 1896 to 1915. It is doubtful whether there will be a similar increase in any subsequent period.

Invention of the cotton gin. — The story of the history of cotton would be incomplete without some attention being given to the work of Eli Whitney. Whitney was born in Massachusetts in

1765 and died in New Haven, Connecticut, in 1825. He was graduated from Yale College in 1792, and in the same year he was employed as a teacher in the home of Mrs. (General) Nathan-



Courtesy of U. S. Department of Agriculture

Fig. 165. — Cotton consumption, foreign and domestic

The mills in the cotton-growing states took 61 per cent of the total taken by the United States mills. Massachusetts, North Carolina, South Carolina, and Georgia are the leading states. Most of the foreign cotton was taken by the mills of New England.

ael Greene, in Georgia. While there his attention was drawn to the difficulty of removing the fiber from the cotton seed. He went to work to overcome this difficulty and soon invented the cotton gin. Whitney's gin was made along such excellent lines that even to-day the gins are essentially the same as his. Although the production of cotton was rapidly failing, the cotton gin gave a great impetus to its production because it did the work of 300 hands in separating the fiber from the seed. As a result of the stimulated production, the exportation of cotton increased by leaps and bounds. We quote the historian Channing, "In 1800 nearly 20,000,000 pounds, worth $5,000,000, were exported, an amount which was exactly doubled in three years, and by 1824 the amount had increased to 142,000,000 pounds, worth $22,000,000."

Cotton manufacturing. — The first factory in the United States was established in Massachusetts in 1788. Hand looms were used until 1815 when power looms began to be used. By 1860 there were over one thousand power looms. At first looms were built in the New England and Middle Atlantic States. At the present time much of the cotton is made into finished products in the South.

The graph (Fig. 165) of the United States shows where the domestic and foreign cotton is consumed in this country. Much of the cotton now used in the United States is manufactured here. Besides, much of the exported cotton is being sent abroad in manufactured form.

Summary. — Cotton is one of the leading crops of the United States. It is the greatest commercial crop because all of it is sold from the farm where it is produced. The prosperity of many people depends directly upon cotton production and the price paid for the cotton crop. It requires six to seven months of warm balmy weather for the maturing of the crop. The United States

produces about 11 to 12 million bales of 500 pounds each yearly. About half of this crop is exported and half of it is used at home. Cotton factories are rapidly being established in sections where the cotton is raised, and the manufacturing plants are being located close to the place where the cotton is grown.

LABORATORY EXERCISES AND HOME PROJECTS

1. Tabulate the number of days required to grow and mature five of the leading crops grown in your locality.

2. Compare a cotton and a wool thread as to strength, flammability, and cost.

3. Study the physical characteristics of cotton and wool fibers.

CHAPTER XXVIII

PRODUCTION OF COTTON (Continued)

Preparation of the seed bed. — The preparation of a good seed bed for cotton is not unlike that for the production of any other crop. The soil should be plowed six to eight inches deep in February, or March, or in many instances in the fall. After the soil is thoroughly plowed, it may be double-disked just previous to planting the seed. Ridging the soil is a common practice and is considered by some as an essential part of thorough preparation.

If cotton follows cotton, rye or wheat should be sown between the cotton rows in the fall, and then the stalks and cover crop should be plowed under in the spring. This is a good practice because the cover crop holds the plant food and protects the soil from erosion and leaching. Grazing the cover crop is a good practice, for it tends to combat the enemies of the cotton plant.

Subsoiling for cotton production, like the same operation in the production of other crops, has seldom been profitable. A fertile soil, well prepared for the seed and kept in good tilth, is a chief factor in the production of a good yield of cotton.

Planting cotton. — Cotton is planted at different dates as follows:

North Carolina	April 15 to May 10
South Carolina	April 14 to May 7
Georgia	April 10 to May 1
Florida	April 1 to May 1
Alabama	April 5 to May 10
Mississippi	April 5 to May 10

Louisiana	April 1 to May 10
Texas	March 15 to May 10
Arkansas	April 15 to May 15
Tennessee	April 15 to May 15
Missouri	May 1 to May 15

It requires a bushel of seed to plant an acre. A bushel of cotton seed weighs from 28 to 33⅓ pounds according to standards set by different states. Cotton is planted in rows 3½ feet apart and rather thickly in the row. After the plants are up, they are chopped out so as to leave one or more sturdy plants every 8 to 16 inches in the row. Montgomery states that if every seed in a bushel were to grow and the plants were the proper distance apart, a bushel would plant 15 or 16 acres. The seed is planted with a one-horse cotton drill, although occasionally a two-horse corn planter is adjusted and used. Seeds should be planted not deeper than half an inch.

Cultivation of cotton. — The cotton plant is less vigorous at the beginning than plants of other tilled crops. There are two main purposes in the cultivation of cotton: (1) to keep down weeds and (2) to conserve the soil moisture. After the plants are 3 to 5 inches tall, the soil is often thrown away from the plants and, within a day or two, turned back again toward the plants. After this the soil is given surface cultivation every 8 or 10 days, the interval depending upon the rainfall and soil conditions. Deep cultivation reduces yields and requires more power. Cotton is cultivated so as to maintain a soil mulch, and from 6 to 10 cultivations may be necessary and practical under different conditions. Late cultivations are helpful in maintaining a soil mulch and in increasing the yield.

Cost of production. — Since cotton is not sold by the acre, there is little need to discuss the cost of producing an acre of cotton. But since cotton is sold by the pound or bale, it is evident that

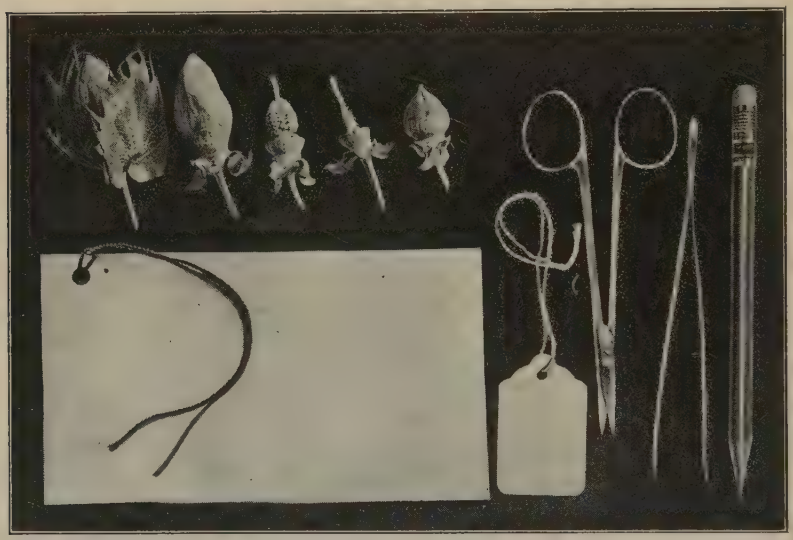
the cost per pound of cotton produced becomes the basis for discussion. The average yield of lint per acre in the United States for 1918 to 1922 was 153.1 pounds. Over the same period the two states having the highest yield were Missouri, with an average yield of 283 pounds, and North Carolina, with 265 pounds per acre; and the two lowest were Florida and Louisiana with 84 and 129 pounds of lint per acre respectively. If the quality, which fixes the price of lint, was the same and if the culture and the value of the land per acre were the same, it is evident, since the farmers of Missouri get more than three times as much lint per acre as do the farmers of Florida, that the cost of production per pound of cotton is approximately one third as much in Missouri as it is in Florida.

Fig. 166. Dixie wilt-resistant variety of cotton

While the cost per acre may vary greatly, yet the cost per pound may be much smaller where the cost of an acre was greater. To produce a large yield per acre with the greatest efficiency and the lowest cost, and at the same time secure a good quality product, means that cotton is produced at the lowest cost.

It is a good practice, and it will have an important bearing on efficiency of production, to study and keep an accurate account of just what it costs to produce cotton.

The cost of producing an acre of cotton will vary somewhat under different conditions; but the cost of producing a pound



Courtesy of U. S. Department of Agriculture

Fig. 167. — Outfit for crossing cotton

Four blossom buds showing the different steps in the operation of emasculation and the small boll which results in two or three days after the cross is made.

of lint will vary a great deal more. According to data in the 1921 Yearbook of Agriculture, covering a survey of 842 farms, it cost $50.65 to produce an acre of cotton and 32 cents to produce a pound of lint. If the yield had been twice as large, then the cost of a pound of lint would have been 16 cents instead of 32 cents. This cost of producing a pound is the important thing, and not the cost of producing an acre. Other things being

equal, as we increase the yield per acre, we reduce the cost of producing a pound of cotton.

The price of cotton does not affect the cost of production, but it does affect the farmer's profits. If the cost of production is 8 cents a pound and cotton brings 12 cents a pound, then the cost of production is 66⅔ per cent of the selling price; but if the selling price is 16 cents, due to improved quality, then the cost of production is only 50 per cent of the selling price.

Factors in the economic production of cotton. — In addition to the topics already discussed the following factors deserve especial emphasis, for it is generally believed they are the foundation stones of economic cotton production: (1) rotation of crops and protection of soil fertility; (2) selecting adaptable varieties; (3) use of barnyard manure; (4) use of commercial fertilizers; (5) combating the enemies of cotton. A brief discussion of each will be given.

1. *Rotation of crops.* — Only a small percentage of farmers in the Cotton Belt practice a regular system of crop rotation. Yet it is well known that crop rotation will increase the yields. Dr. E. R. Loyd, director of the Memphis Chamber of Commerce, recently in an address to the farmers of Cape Girardeau, Missouri, advised the cotton farmers to practice a system of diversification including in the plan a few dairy cows, a few hogs, some poultry, a good garden, and some cotton. To farm in accord with this advice would make the farm self-supporting, maintain the fertility of the soil, distribute labor, cause the cotton yields to be larger because of the system practiced, and make the cotton crop a cash crop. Fewer acres of cotton under this plan will return a larger total yield. Changes in labor conditions and the ravages of the insect enemies of cotton are giving further impetus to the practice of rotation.

This is a rotation recommended as a good one for the cotton farmer:

First year . . . . . corn and peas
Second year. . . . . wheat and peas
Third year. . . . . cotton plus cover crop in the fall and winter

The Georgia Station attributes its good station yields to crop rotation. They have found that cowpeas constitute one of the most valuable parts of the rotation system. The South Carolina Station suggests the growing of early-maturing varieties of cotton, plowing the cotton stalks under in the early fall or late summer, and then sowing the ground to a cover crop. Farmers have reported an increase of half a bale to two bales per acre where cover crops are used in the fall and winter.

2. *Selecting adaptable varieties.* — There is no variety of cotton adapted to all the soil types and different climatic conditions of the Cotton Belt. In upland types early maturity is correlated with small bolls and dwarf plants. The rank-growing plants with large bolls are known as later-maturing sorts. The shorter seasons farther north produce varieties which mature earlier, and in the South varieties are grown with longer staple, requiring a longer period for growth. Uplands and lowlands are adapted to different types and varieties.

To maintain the purity of cotton seeds is very difficult, because in ginning the seeds of different varieties are often run together and also because cotton is pollinated in the field by insects. Continued selection to maintain the purity of the varieties is very important. Selected varieties not only yield more but produce a more uniform staple and hence bring a better price when sold to the manufacturer. Farmers' Bulletin No. 501 says, "Experiments justify an estimate of at least a 10-per cent

increase in yield, as a result of selection, with a still greater increase in the quality and market value."

On the demonstration farm of the Southeast Missouri State Teachers College the three leading varieties of cotton in 1923 yielded as follows:

	Pounds per Acre	Percentage of Lint to Seed
Wanamaker	2312.2	33.9
Trice	1945.5	29.6
Express	1911.6	28.0

The Trice and Express varieties matured earlier than did Wanamaker, and for that reason are recommended for this section. Acala and Delphos are also recommended for Missouri.

Whole communities in coöperation with the Experiment Station of their state may combine to produce good seed cotton. If a whole community will grow a single variety, then mixing will be prevented. Selection should be done with the utmost care, and at the proper time all the plants not true to the variety should be removed from the field. Such community action will add revenue to the people so coöperating. The value of the services rendered by the Experiment Station can not be estimated. To produce better varieties that have a longer staple and larger bolls, that are resistant to disease, and that mature early is of great worth; but to accomplish these things the work should be directed by one with a scientific knowledge of the principles involved. Different varieties of cotton vary much in their yielding capacity under different conditions. In South Carolina (Bulletin No. 50) it was found that Cook produced 719 pounds of lint; and Webber 49, only 409 pounds. In the experiment seven varieties produced over 600 pounds of lint to the acre,

and six varieties produced less than 500 pounds. The North Carolina Station (Bulletin No. 120) found that short-staple cotton yielded 664 pounds an acre, while under the same conditions long-staple cotton yielded 417 pounds to the acre. At the Georgia Station some varieties yielded as much as 650 pounds of seed cotton, while others, growing by their side, yielded only 260 pounds.

It is generally best to get seed near where it is to be grown. Getting an adaptable variety is an easy and cheap way to increase yields.

3. *Use of barnyard manure.* — Cotton lint removes only a trace of soil fertility, since cotton lint is almost pure carbon. But when the stalks are burned, or when the cotton seeds are taken off the farm, considerable quantities of fertility are removed. The cotton plant should be plowed under so that the organic matter of the soil may not be depleted. The amounts of the elements removed by a ton of cotton stalks and by 300 pounds of lint or seed are as follows:

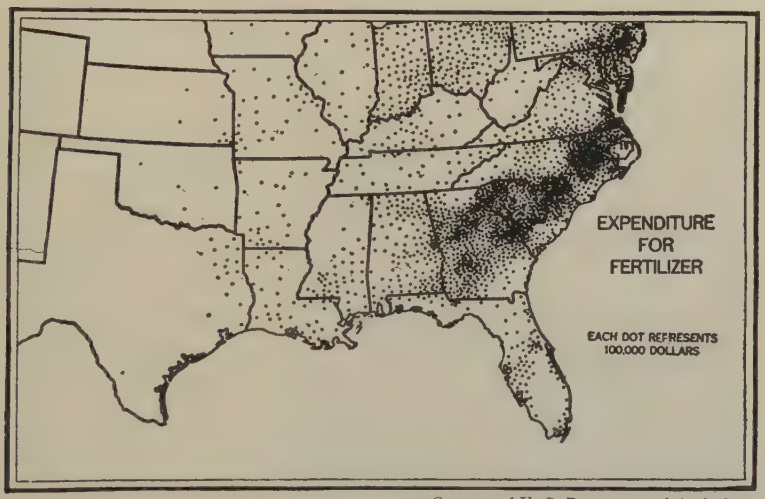
Soil Fertility in Cotton Lint, Cotton Seed, and Cotton Stalks

	Nitrogen (Pounds)	Phosphoric Acid (Pounds)	Potash (Pounds)
Cotton stalks — ton . . .	130.2	47.2	59.0
Lint — 300 pounds . . .	0.63	0.23	2.0
Seed — 600 pounds . . .	19.0	6.88	6.88

Cotton lint removes little soil fertility, but the seed removes a great deal. Continued cotton cropping slowly but surely depletes the soil if both seed and lint are sold and no provision is made to replace the fertility removed.

Since it pays to get good yields per acre, it behooves the cotton farmer to apply his barnyard manure to cotton fields.

(See p. 87.) Cow manure adds three times as much nitrogen as is removed by cotton lint, three timesas much phosphoric acid, and almost as much potash. Therefore applying 8 to 10 tons of manure per acre will add more soil fertility than is removed by several cotton crops, provided the lint is sold and the rest of the plant is returned to the soil. In Alabama with



Courtesy of U. S. Department of Agriculture

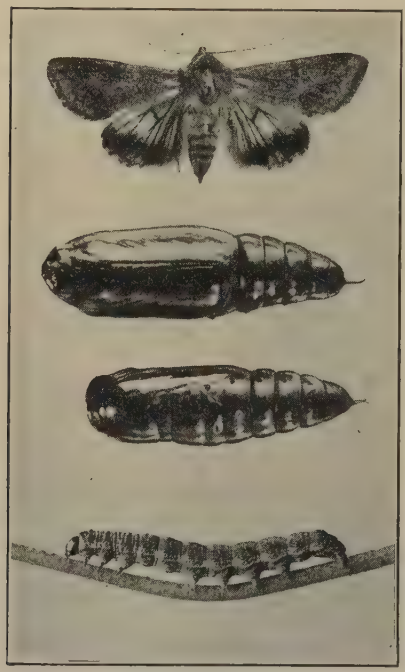
Fig. 168. — Distribution of the expenditure for commercial fertilizers

extensive experiments the addition of two tons of stable manure increased the yield 444 pounds per acre, and 835 pounds of fresh cotton seed applied per acre increased the yield 288 pounds. It is more profitable, however, to sell the seed for feed purposes and to return the amount of plant food they contain in some commercial form.

A green cover crop sown in the fall, such as rye, wheat, or oats, will help to hold the soil and provide winter pasturage, and then it may be plowed under early in the spring. This will not only

hold the plant food but prevent washing and do much to protect the soil.

4. *Commercial fertilizers.* — The use of commercial fertilizers in cotton production is increasing (Fig. 168). Much money is annually expended for it, and farmers should inform themselves so that fertilizers may be purchased and used intelligently. Farmers should know what their soil needs and then supply fertilizers accordingly. Sandy soils usually have a low supply of nitrogen and phosphorus, but are fairly well supplied with potash. A clay soil has a fair supply of nitrogen, especially when legume organic matter is added, and is reasonably high in phosphorus and potash. A black loam soil has a good supply of each of the fertilizer ingredients. (See p. 109.) A 200-pound application of commercial fertilizer does not add much fertility and should not be depended on by itself to keep up the fertility of the soil. Commercial fertilizers do not deplete soil fertility, but to get the best results from them plenty of organic matter should be added to the soil.



Courtesy of U. S. Bureau of Entomology

Fig. 169. — Cotton bollworm

At top, adult; in middle, pupæ; at bottom, larva.

Each fertilizing ingredient has a specific function in the pro-

duction of cotton. Nitrogen promotes growth and leafiness; phosphoric acid hastens maturity as much as one to two weeks; and potash improves the quality of lint and makes the plant more resistant to disease.

The amount of fertilizer used per acre ranges from 200 to 800 pounds. At the South Carolina Station in a thirteen-year trial (Bulletin No. 211) with the application of fertilizer at the rate of 800 pounds per acre, the average production was 511 pounds of lint, whereas where no fertilizer was used the yield was 371 pounds per acre. At the Georgia Station 400, 800, and 1200 pounds of fertilizer were used and in each case increased yields resulted. Two hundred pounds of fertilizer is most frequently used. The fertilizers used are acid phosphate, muriate of potash, nitrate of soda, kainite, and cottonseed meal.

Courtesy of U. S. Bureau of Entomology

Fig. 170. — Boll-weevil larva in a cotton square

5. *Combating the enemies of cotton.* — There are two kinds of enemies of cotton: insects and fungous diseases. The insects which do so much harm are the boll weevil, the pink bollworm, and the cotton bollworm. The boll weevil is the greatest enemy of cotton and causes hundreds of thousands of dollars' loss annually. The boll weevil has four stages in its life: (1) egg; (2) larva, or grub, stage, which is the growing period; (3) pupa

stage, a period of inactivity; and (4) adult stage. It is during the larva stage that they do the harm.

(1) Only about six per cent of the weevils hibernating in the fall survive the winter, and freezing weather reduces the per cent surviving. They hibernate under rubbish or old cotton plants left on the ground, in fence corners, in the debris around the field, and under leaves. Then the first line of attack on the boll weevil is to resort to fall destruction of cotton stalks. The 1921 Yearbook of Agriculture says, if the cotton plants are plowed under before the first killing frost in the fall, the number of boll weevils will be greatly reduced. The farmer, therefore, should clean the fence corners and burn all ditch banks, stumps, and other rubbish where the weevils hibernate.

Fig. 171. — Cotton-boll weevil

(2) Rotation of crops tends to reduce the boll-weevil injury. It will increase yields; then why not practice rotations? Corn, cowpeas, and cotton in rotation and a winter cover crop of rye will help to reduce the boll-weevil damage.

(3) The time required for the boll-weevil egg to incubate and hatch, and the insect to mature is about 25 days. The weevil multiplies rapidly just like some other insects. Therefore early planting and the use of early-maturing varieties are means of evading the last generations of the boll weevil.

(4) Cotton fields should be pastured. Cattle will eat many of the weevils. This is another reason why the cotton farmer should diversify. In years when the boll weevil is abundant, diversified farming receives a powerful impetus.

(5) Calcium arsenate should be used in the dust form as a spray. This spray is the most successful now known (Fig. 172).

Other insect enemies of cotton may be largely controlled at the same time by the methods used in combating the boll weevil.

The fungous diseases also do a great deal of harm. (1) Cotton wilt is a fungous disease that remains in the soil for years. It

Fig. 172. — Poisoning the cotton-boll weevil

A horse-drawn machine is here being used to make the spray of calcium arsenate.

enters the roots and stops up the water vessels. There is no remedy, but the U. S. Department of Agriculture has developed wilt-resistant varieties, which grow under wilt-infected conditions (Figs. 54, 166). (2) Rust is a disease which defoliates the plant and finally causes it to die. Potash fertilizers or manure will help to invigorate the plants and prevent the rust to a large extent. (3) Texas root rot is due to a soil fungus which

causes cotton, alfalfa, and other plants to wilt and finally die. No effective remedy for root rot is known. (4) Anthracnose is a fungous disease occurring throughout the Cotton Belt. It causes a damping off of the young plant and is most harmful in causing boll rot in wet weather. It is distributed through

Courtesy of U. S. Department of Agriculture

Fig. 173. — Seedlings of cotton attacked by anthracnose

infected seed. Crop rotation and the use of seed free from anthracnose are the preventive, or control, measures (Fig. 173).

Summary. — How to produce the greatest amount of fine-quality cotton at the lowest cost is the important thing. The factors helpful in increasing production are: (1) proper preparation of the seed bed; (2) proper planting and getting a good stand; and (3) proper cultivation. The factors which will reduce the cost of production are: (1) rotation of crops; (2) using adaptable

varieties; (3) use of barnyard manure; (4) proper use of commercial fertilizers; and (5) combating the enemies of cotton.

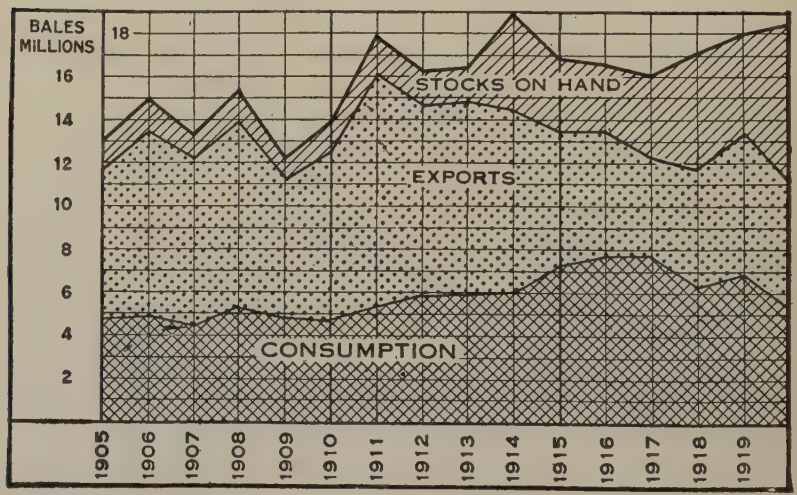
LABORATORY EXERCISES AND HOME PROJECTS

1. Let every pupil grow cotton on an area of $\frac{1}{10}$ of an acre. Keep a complete record of the project.
2. Trace a cotton fiber in its probable route from producer to user.

CHAPTER XXIX

MARKETING COTTON

Cotton a great commercial crop. — Cotton is the greatest commercial crop of the United States. All of the cotton is sold from the farms where produced. About half of the crop is exported. The amount kept in the United States and the amount exported are shown in the following graph:



Courtesy of U. S. Department of Agriculture

Fig. 174. — Cotton consumption, exports, and stocks on hand

Previous to 1914, almost all the surplus cotton was exported, and the volume of exports exceeded home consumption. Stocks on hand are steadily increasing.

From the graph it may be seen that about half of the cotton crop is exported. The average annual value of the cotton crop ex-

ported from 1915 to 1921 was about $6,500,000. During the same period the wheat exports stood second highest with an average annual export trade value of over $4,000,000. The tobacco, hay, and corn export trade for the same period amounted to $1,240,000, $1,000,000 and $750,000 respectively.

Cotton is essentially a commercial crop, for only about half of the cotton consumed in the United States is used in manufacturing by the mills in the states where the crop is grown; the other half is shipped to the mills of the Northern states and there manufactured into finished goods. The center for manufacturing cotton is rapidly moving toward the South. Fig. 175 illustrates these points.

Warehousing for cotton. — In marketing cotton, the warehouse plays an important part. In 1920 there were 2735 cotton warehouses in the United States. Georgia had 775; Texas, 756; Alabama, 282; South Carolina, 269; Mississippi, 133; Oklahoma, 127; Arkansas, 109; North Carolina, 105; Louisiana, 46; California, 31; Tennessee, 30; Virginia, 23; and Arizona, Florida, Missouri, New Mexico, and Kentucky had 22, 20, 4, 2, and 1 respectively. Many claims are made by experts with reference to advantages to be derived from the storing of cotton both to the staple itself and to the farmer.

In some sections cotton is left exposed on the ground. This causes considerable loss each year. Damage of cotton due to exposure in this manner is known as "country damage." Although cotton does not readily absorb moisture, yet when it is exposed it is readily discolored and the fibers are weakened. "Country damage" to cotton should be avoided by protecting cotton by storage, for it means more money to the farmer and a better product for the consumer.

Market classes of cotton. — Cotton is sold according to market class and grade. Ignorance of these factors results in a great

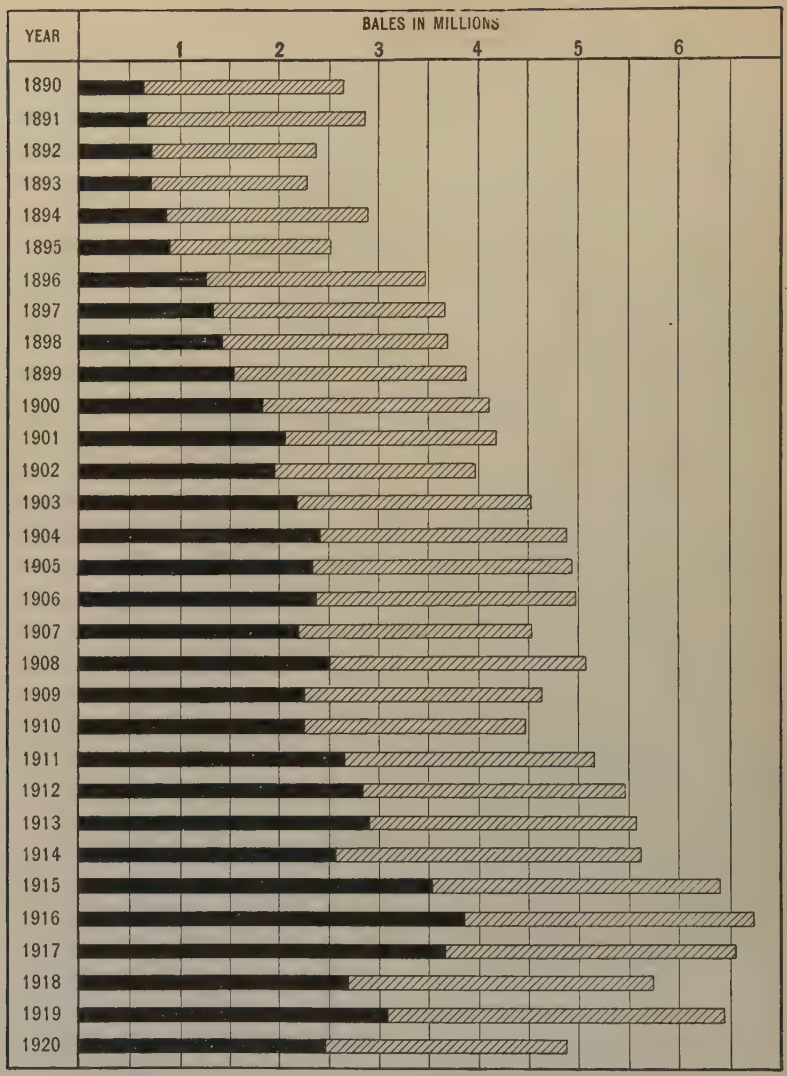


Fig. 175. — Raw cotton taken by United States mills

The black bar represents millions of bales used by Northern mills. Southern mills now take more than half of the cotton.

deal of loss to the seller, and the knowledge of them results in larger profits to the buyer.

Courtesy of U. S. Department of Agriculture

Fig. 176. — Comparative lengths of lint of certain varieties of cotton

Cotton is classed on the basis of length, strength, uniformity, color, and cleanliness of fiber. Long, strong, uniform, pure white or creamy white, clean fibers are classed as the best cotton.

According to their value, there are nine grades of white cotton. These nine grades in the order of their value are: (1) middling fair, (2) strict good middling, (3) good middling, (4) strict middling, (5) middling, (6) strict low middling, (7) low middling, (8) strict good ordinary, and (9) good ordinary.

Since middling is the basis for the classification of cotton, it also becomes the basis for fixing the price of the different classes and grades of cotton.

The United States Department of Agriculture has sent out about 2500 samples of cotton standards. The classes and grades of cotton thus suggested and known as The United States Official Cotton Standards are virtually followed in all cotton markets at the present time. Foreign markets are also rapidly adopting these standards.

Cotton markets.. — The principal countries exporting cotton are United States, British India, Egypt, Peru, and Brazil. The leading countries importing cotton from these producing countries are given in Fig. 177.

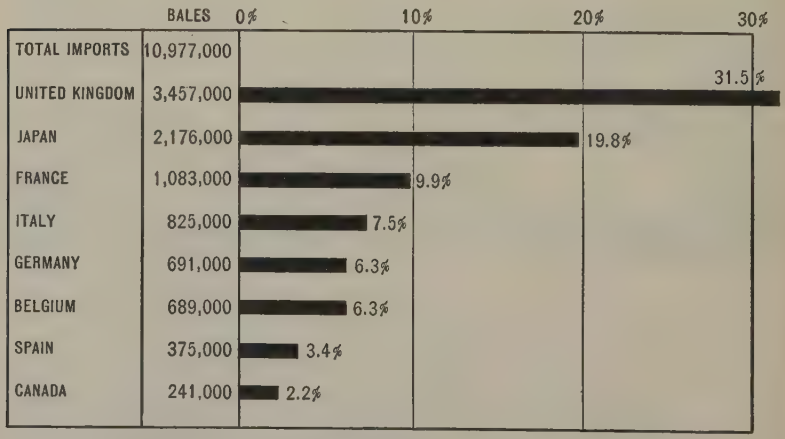
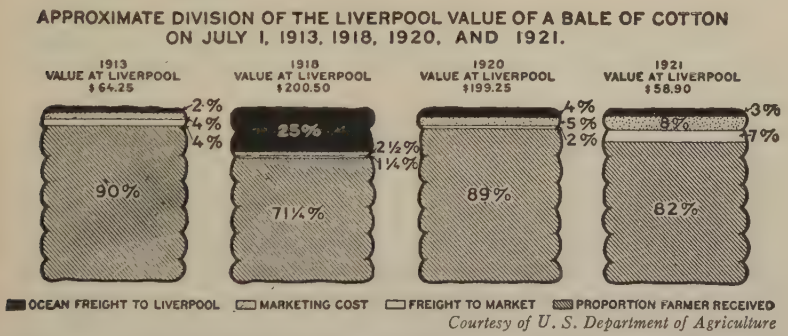


Fig. 177. — Cotton imports for principal countries, 1920

The market price in Liverpool to a considerable extent controls the price of cotton; and the price received by American farmers may be the price quoted in Liverpool, minus the cost of transportation and other risks involved. In other words, the farmer has to pay the cost of transportation. This is not the case with manufactured goods, for the price of the manufactured article is set at the factory, and the user of the article pays for the cost of shipping it. The approximate distribution of the money received by different persons engaged in handling cotton is shown in Fig. 178.



Courtesy of U. S. Department of Agriculture

Fig. 178. — **The farmer's share of the final market value of a bale of cotton**

Price of cotton. — The average farm price of cotton in the United States on the first of December for a number of years follows:

Year	Average Price per Pound (Cents)
1876–1885	9.1
1886–1895	7.7
1896–1904	7.7
1905–1914	10.7
1915–1921	22.0

The price of cotton varies from year to year. The three years since 1908 when the average prices (based on the price the first day of each month) were the lowest were 1914, 1908, and 1915, the prices being 9.1, 9.6, and 9.7 cents per pound respectively. The three years when the prices were the highest were the years 1918, 1919, and 1920, the prices being 31.3, 29.4, and 26.6 cents respectively.

Every United States Yearbook of Agriculture will give the prices of cotton year by year for the last 30 or 40 years. It is never urged that these figures be memorized, but a close study of such data becomes of much value to the farmer. Ignorance is the one thing upon which speculation thrives; but common knowledge about a commodity, such as cotton, leads to stabilization of the trade.

From the preceding data, from the fact that the enemies of cotton are constant and severe, and from the further fact that the wool crop is rather light in the United States, it may be concluded that the prices on cotton will be reasonably good in the future. But the cotton farmer should analyze the situation regarding cotton prices constantly.

How the farmer may help to stabilize cotton prices. — It is admitted by all except the speculator that stabilized prices are best for producers, bankers, merchants, people interested in transportation, and practically everybody else. It is in those years when prices fluctuate greatly and when speculation is rampant that mortgages are foreclosed and people go to pieces on the rocks of bankruptcy. It is well known by the farmer that the production and marketing of cotton which has long, strong, well-twisted, and unbleached fibers and which is free from dirt, trash, and sticks will do much to stabilize prices. But in addition to this, there are several other things which the farmer may do to help stabilize prices:

1. The farmer should study the market; not only for the time when he is selling his crop, but for the entire year and for past years as well. This may be done by studying the United States Yearbooks of Agriculture, and especially the latest issues. Bulletins and daily papers which quote cotton prices and have market reports are also very helpful.

2. Selling the crop gradually and at a uniform rate will do more to stabilize prices than anything else. The cotton crop is now sold by farmers in the following manner as to time; the table shows six-year averages:

January . . 9.0%	May 2.2%	September . 14.1%
February . . 5.9%	June 1.6%	October . . 21.8%
March . . . 5.2%	July 1.1%	November . 19.8%
April . . . 3.8%	August . . . 1.2%	December . 14.4%

The above data show that 70 per cent of the cotton crop is sold in the four months of September, October, November, and December; and that only 6.1 per cent of the crop is sold during the four months of May, June, July, and August. It is this dumping of the staple on the market which the farmer must prevent. Marketing $\frac{1}{12}$ of the product monthly or, better still, $\frac{1}{52}$ of the product weekly, will do much to stabilize cotton prices. The time to sell cotton is when the trade wants to buy. When does the trade want to buy? When it needs the product. Cotton must be sold when it is wanted by the trade and that is from time to time as the raw cotton can be manufactured into a finished product.

3. Another thing that is helping to stabilize the price of cotton is the methods used by the American Cotton Growers Exchange, a coöperative organization of farmers who try to market cotton in an orderly way. This coöperative way of

marketing cotton means much to the cotton farmers in stabilizing prices.

Marketing cotton coöperatively. — Marketing cotton coöperatively is an excellent system, but the system will not work of its own accord. The combined intelligence of the ablest men in the industry is demanded by a marketing organization. Even then mistakes will be made; but the mistakes will not be so many or so costly as those made by the individual farmer who does not take the time to study the markets and other conditions of marketing.

The individual producer of cotton is unable to undertake many of the endeavors which are of vital importance to better and more economical marketing; but organizations are supplying many communities with the means for carrying out the ideas of orderly marketing. The individuals make the group, and the group can do many things that the individuals alone can not do.

Coöperative marketing can accomplish: (1) the growing of a product which is well standardized as to class and grade; (2) the storing of cotton in a good warehouse and protecting it well; (3) the purchase of needed supplies in large quantities, thereby making a saving; (4) the employment of a competent marketing agent, who will be worth much to the growers; (5) the opening up of new markets; (6) the obtaining of warehouse credit on stored cotton.

The Cotton Growers Exchange has done much to assist not only the members of the Exchange but also the cotton growers in securing better prices because the Exchange causes cotton to be marketed in an orderly fashion. It does not dump the cotton, but it markets it when there is a demand, presumably about $\frac{1}{52}$ of the entire crop weekly. This helps greatly in stabilizing cotton prices.

Successful coöperative marketing. — The essentials of success in this undertaking are: (1) sufficient business, so that the overhead expenses are not large in proportion to the total business done; (2) coöperative principles; that is, the organization must

Photo by Foltz

Fig. 179. — Loading cotton at Savannah

be democratic and managed for all participants, and not for a few. If there is a distribution of profits, they must be distributed according to the money invested. It should be remembered, however, that a coöperative association is not to make profits, but rather to effect savings and to render service. The membership in coöperative marketing associations should be limited to producers only, and speculators must be kept out.

Pooling sales. — Pooling is an important feature of coöperative marketing of cotton. By pooling is meant the averaging of returns received for cotton sold during a certain period, so that all growers receive the same price for the same grade of cotton sold by the entire organization. This protects the individual member from loss because of unfavorable market conditions of a temporary nature. The length of the pool varies in time from three to six, or it may be for twelve months.

The manager. — The keystone to successful coöperative marketing of cotton is a competent, efficient manager. A well-qualified manager must be employed at an attractive salary, and then must be given loyal support and complete authority to act as he deems best. He must know the cotton situation as nearly as it can be known. He must consider the conditions and then act.

Summary.. — Cotton is the greatest commercial crop of the United States. About half of the crop is exported to foreign countries, and half of the rest of the crop is shipped to manufacturing centers of the North. To make of cotton a good commercial crop, it is best to produce a quality product and to sell it according to a definite market class and grade. Marketing about $\frac{1}{52}$ of the cotton crop weekly is essential for securing the best prices, and coöperative marketing helps greatly in causing the crop to be marketed in an orderly way.

LABORATORY EXERCISES AND HOME PROJECTS

1. Find data on total production and price of cotton for the last 15 or 20 years from the United States Yearbook on Agriculture. From the data gathered, predict, as best you can, the future price of cotton.
2. With your father's or a neighbor's help estimate the cost of producing an acre of cotton; a pound of cotton.
3. State and discuss the qualities the cotton fiber should possess.
4. Name and discuss the market classes of cotton; and get from the newspaper the market quotations.

CHAPTER XXX

OTHER FIELD CROPS

Important sectional crops. — There are some field crops that, because of soil or climatic conditions, are more or less limited to certain sections of the country. Of these there are two of considerable commercial importance that will require brief treatment: tobacco and peanuts. The former is commercially the more important (Fig. 60). It has had an almost continuous increase in production during the last forty years. The rate of increase has more than kept pace with the increase of population. Domestic consumption, too, has been increasing steadily for many years and even on a per capita basis this increase has been considerable. Tobacco differs from all other crops discussed because it is neither a food nor a fiber plant.

On the other hand, the peanut is rapidly growing in commercial importance, being used both as a food for man and animals. This plant belongs to the legume family and besides the merits peculiar to itself it possesses in a greater or less degree the characteristics of the legumes.

Tobacco

Importance. — Tobacco is one of our important commercial crops. For the five-year period ending 1920 the average acreage value of the crop was $205, as against $126 for potatoes, $42 for cotton, and $26 for hay. However, in acreage tobacco occupies only five tenths of one per cent of the land in all crops, and in total value it produces a little less than three per cent of the value of all crops.

Tobacco states. — Kentucky produces about twice as much tobacco as any other state. North Carolina ranks second. These two states produce more than half of the crop of the entire United States. In 1923 Kentucky produced 420,280,000 pounds and North Carolina produced 386,400,000. The total production for the same year in the United States was 1,474,786,000 pounds.

Photo by Cook

Fig. 180. — Tobacco plant with blossoms

Culture. — Tobacco seed are very small and therefore may be mixed with sand and then sown in a well-pulverized seed bed. A teaspoonful of seed will sow 100 square feet. The young plants are transplanted into a well-prepared seed bed which should be reasonably fertile; however, a light soil will produce a lighter, better flavored tobacco. The soil growing tobacco should be frequently cultivated, for this will tend to conserve the moisture, promote growth, and keep down the weeds. The plants should be suckered and topped at the proper time. According to the 1922 Yearbook of Agriculture, costs in producing different types of tobacco varied from $64 to $113 per acre.

Harvesting the crop. — The plants should be cut when the leaves begin to show a yellow, matured tinge. After the plants

have been cut and have wilted, they are piled up, and when in the proper condition they are hauled to and hung up in a tobacco curing house, where the tobacco is air-cured. The buildings used in curing must be well ventilated. They are kept open during the day, but in damp or rainy nights the ventilators

© *H. P. Cook*

Fig. 181. — Field of tobacco in Virginia

are closed. Some tobacco is cured with stove heat. Curing is very important in securing the best quality of tobacco.

The tobacco worm. — This enemy, known as the *hornworm*, is the worst insect pest of the tobacco crop. When not abundant, they are picked off by hand; but if many are present, arsenate of lead paste may be used as a spray to destroy them. Four pounds of this paste added to 50 gallons of water make an

effective spray. However, the powdered arsenate of lead may be used in the place of the paste.

Peanuts

History. — It is generally believed that peanuts had their origin in Brazil, South America. From America they were introduced into the Old World, where their culture on a commercial scale was begun much earlier than in America. Their development on a commercial scale in the United States dates back to 1870. There were 866,000 acres of peanuts grown in 1923, and the yield was 636,462,000 pounds.

Courtesy of U. S. Department of Agriculture

Fig. 182. — Peanut plant showing "pegs"

Description. — The seeds, like those of other legumes, are two-lobed (dicotyledonous) and the stems are like the stems of the clovers. Each leaf has four leaflets and is net-veined. Like the other legumes peanut roots harbor bacteria which form many nodules and, in this manner, store nitrogen in the soil. The flowers of the plant are borne on axillary trailing stems (Fig. 182) and the fruit or pods are matured in the ground.

Peanut-growing states. — The peanut is a tender plant and is easily killed by frost. It grows best in a sandy loam soil and in

warm climates. The principal states growing peanuts are given in the following table:

PEANUT PRODUCTION, 1922

	POUNDS
United States	623,507,000
North Carolina	113,665,000
Alabama	112,750,000
Georgia	96,320,000
Texas	96,320,000
Virginia	78,000,000
Florida	44,928,000

South Carolina, Mississippi, Arkansas, and Oklahoma each produced around 12,000,000 pounds in 1922. The average yield of peanuts per acre in 1923 was 720 pounds. This was the largest average yield per acre during the last five years according to *Crops and Markets*, a government publication (January, 1924).

Culture. — Peanuts require a warm soil and hence are usually planted about May 1 to 15. It requires one peck of hulled seeds or six pecks of peanuts in the hull to plant an acre. They are drilled from 30 to 36 inches between rows, and the spacing in the row ranges from 8 to 12 inches.

A good fertile well-prepared seed bed is essential in securing profitable yields. The culture of peanuts is like that of corn and cotton. Maintaining a loose soil mulch helps the slender portion called the "peg" to penetrate the ground and permits the fruit to develop properly (Fig. 182).

Harvesting. — When the leaves turn yellow, it is a sign that the nuts are matured. Where peanuts are grown on a commercial scale, they are dug with horsepower diggers. On a small scale

they are dug with hand diggers. After they are dug they are put in a shock in which they are allowed to cure (Fig. 184). Leaving the nuts in the rain discolors them. This reduces the price and the salability.

Uses of peanuts. — Roasted peanuts are an excellent food for man. The peanut kernel has a fine composition. Its ingredients

Courtesy of U. S. Department of Agriculture

Fig. 183. — Peanut field

are highly concentrated and therefore it should be used in limited quantities. Where so used, it supplements nicely the carbonaceous cereal foods so commonly used in the United States.

The peanut is of great importance as a pasture crop for hogs, which harvest the pods, and the hay makes a good feed for all kinds of cattle.

The high food value of peanut kernels, which are coming into such large use as to be important in the confectionery and grocery trade, can best be seen by comparison with cow's milk, a standard article of diet.

Composition of Peanuts Compared with Milk

	Dry Matter	Protein	Carbo-hydrates	Fats	Nutritive Ratio
Peanut kernel . .	94.7	27.4	10.0	42.9	1 : 3.9
Cow's milk . .	12.8	3.5	4.9	3.7	1 : 3.8

Courtesy of U. S. Department of Agriculture

Fig. 184. — Building peanut shocks

Note the wooden form about which the shock is built.

LABORATORY EXERCISES AND HOME PROJECTS

1. If tobacco is grown in your section, make a tobacco survey similar to former surveys that you have made.

2. From the Yearbook of Agriculture secure data and make a graph of the tobacco-producing states similar to the graphs in this book.

3. Determine the percentages of hulls and kernels in a sample of peanuts.

4. Compare the botanical features of the peanut plant with some of the clovers. The plants compared should be in the hands of the pupil.

PART THREE

HORTICULTURE

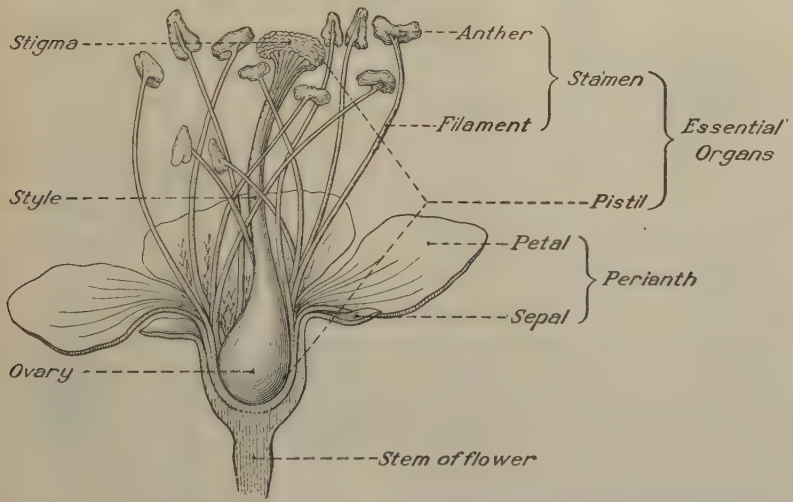
Photo from Brown Bros.

An apple orchard in blossom

CHAPTER XXXI

PLANT PROPAGATION

Plant propagation by seeds. — *Formation and distribution of seeds.* — Plants are multiplied most frequently by seeds. A corn kernel may reproduce a thousandfold annually, a wheat kernel



From Peabody and Hunt's Biology and Human Welfare

Fig. 185. — Parts of a flower (plum blossom)

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: apple, pear, or cherry flowers; seeds which have special devices to aid their dissemination; a propagating box; one-half pound of tallow; one pound of beeswax; two and one-half pounds of rosin.

a hundredfold, a single pigweed seed may produce two hundred thousand seeds, and an apple tree may grow millions of seeds annually. Seeds are nature's most universal way of propagating higher forms of plant life.

Flowers are essential to seed development. Before a seed can begin to grow there must be a flower. A *perfect flower* has four parts: the calyx, the corolla, the stamens, and the pistil. The stamens and the pistil are the organs of reproduction. The stamens are the male organs of the flower, and the pistil is the female organ. The stamens produce the pollen. When the pollen falls upon the top part of the pistil, the flower is said to be pollinated. If proper conditions for growth are present, the pollen grain begins to grow and to develop a pollen tube. This pollen tube grows down the hollow opening in the pistil to the ovary. As soon as the pollen tube penetrates the ovary of the flower, the flower is said to be fertilized. Seeds do not form until the ovary is fertilized. Extremely wet, rainy weather and very hot, dry weather hinder the processes of pollination and fertilization. When corn tassels dry up, the pollen grains lose their power, fertilization does not take place, and the plant produces barren ears.

Fig. 186. — Pollen escaping from anther (B); germinating on stigma (A)

Imperfect flowers are flowers that have only one of the organs which make a perfect flower. In imperfect flowers either the stamens or pistils are absent. Some varieties of strawberries, cucumbers, and muskmelons bear imperfect flowers. Imperfect flowers can not reproduce until they are fertilized by the pollen from some other flower. Occasionally when strawberries bloom but do not fruit, the flowers are imperfect. The gardener should

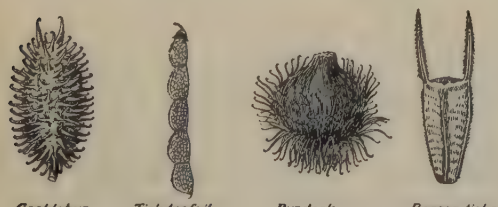
plant by the side of barren plants a variety which contains both stamens and pistils.

After seeds are matured, they are scattered by nature's methods: wind, water, animals, birds, and man.[1] Every plant must have room to grow, and it is for this reason that seeds must be widely disseminated. This is nature's way. Seeds fall upon places not conducive to their growth, but man provides a well-prepared seed bed in which seeds can grow. In nature only the most fit survive; but man often perpetuates both weak and strong seeds alike.

From Peabody and Hunt's Biology and Human Welfare

Fig. 187. — Fruits and seeds dispersed by wind

Three essential conditions for seed germination. — Before seeds will grow, there are three factors which must prevail. These three factors are proper moisture, proper temperature, and free air (oxygen).



From Peabody and Hunt's Biology and Human Welfare

Fig. 188. — Fruits and seeds dispersed by animals

1. The seeds of the water lily will grow in the presence of free water, but corn will not germinate in water. It will sprout best in a soil having about 20 to 25 per cent of moisture. Some other seeds will germinate in semiarid regions. The amount of

[1] **Note to the Teacher:** The appendages that seeds have which facilitate their distribution may be studied at this point.

moisture may be controlled to a considerable extent by tillage and drainage.

2. Each kind of seed has a minimum, a maximum, and an optimum temperature at which it will germinate.

Table Showing Temperature at Which Seeds Germinate

Seed	Minimum	Optimum	Maximum
Corn	41°–51° Fahr.	99°–111° Fahr.	111°–122° Fahr.
Wheat . . .	32°–41° Fahr.	77°– 88° Fahr.	88°–108° Fahr.
Oat	32°–41° Fahr.	77°– 88° Fahr.	88°– 99° Fahr.
Bean . . .	41°– Fahr.	77°– 99° Fahr.	88°– 99° Fahr.
Melon . . .	60°–65° Fahr.	88°– 99° Fahr.	111°–122° Fahr.
Red clover . .	88°–99° Fahr.	99°–111° Fahr.	111°–122° Fahr.

Some seeds will germinate at temperature just above freezing; others require warm summer conditions for their best growth. Soil temperature may be controlled to some extent by tillage, by drainage, by turning under vegetable matter, and by choosing the right season.

3. There must be air present if seeds are to germinate. Seeds germinating in the water get air needed for their germination from the water, and seeds growing in the soil get soil air needed for their growth. Tillage opens the soil and aids air circulation.

Plant propagation by layering. — Many plants and practically all vines can be multiplied by layerage. This means partially covering the decumbent shoots and runners with earth, under which new roots form. In a year good plants may be thus secured. Dewberries, raspberries, and grapes are readily propagated by layers (Fig. 189).

Plant propagation by cuttings. — Plants may be propagated by three kinds of cuttings: root cuttings, hard and soft wood cuttings, and by leaf cuttings.

Blackberries and raspberries may be propagated by root cuttings. Hardwood cuttings are made from perennial plants. Grape cuttings belong to this class. Certain plants like Rex begonia and Gloxinia may be propagated by leaf cuttings.

Fig. 189. — Compound layering
By this method several new plants are produced from the same shoot.

Technique of cuttings. — Cuttings should be cut on a slant, just beneath a bud or leaf. The reasons for this are: (1) More surface is exposed. (2) There is supposed to be more food at the nodes than at the internodes. (3) Roots will grow at the nodes more readily. A plant cutting with one or two buds above the ground and several below is illustrated in Fig. 191.

One leaf should be left on the cutting for the following reasons: (1) It reduces transpiration. (2) It encourages circulation of plant foods. (3) The green part of the leaf aids in the manufacture of plant foods.

Medium for propagating cuttings. — A good medium for propagating cuttings is a coarse, sharp sand, for the following reasons: (1) It permits free air circulation. (2) It permits free water circulation and may easily be kept moist, yet does not become water-logged. (3) Its temperature can be kept fairly even, if kept away from the direct sunlight. (4) It is generally free from organic matter, which by decaying produces bacterial and fungous diseases.

Fig. 190. — Grape cutting

Plant propagation by graftage. — *Reasons for graftage.* — Grafted plants produce fruit like that of the parent plant, and seedlings produce fruit smaller than the parent plant. Seeds are often the result of two parents and therefore not true to type. A hundred seeds from the same tree may produce as many different varieties, but a hundred grafts from the same tree will produce the same kind of fruit. Plants may be changed in size by grafting. Grafting on plants that have smaller root systems dwarfs the plant, but grafting on vigorous root systems increases the plant's size. If pears are grafted on quince roots, the result is a dwarfed plant. Also, conversely, if the quince is grafted on the pear, the resulting plant is larger than the quince.

Fig. 191. — One style of chrysanthemum cutting

Grafting may be used to adapt plants to adverse soils. Plums thrive best in moist soils; peaches do best in fairly dry, porous soils. These plants may be budded one upon the other, and thus the plant may be made to grow in an otherwise unfavorable soil.

Grafting is sometimes used to make barren plants fruitful. Fruit trees may be top-grafted, and thus the stock which has a good root system may be used to advantage. A barren tree may thus be made fruitful.

Propagation by bud graftage. — Bailey[1] says: "Budding is the operation of applying a single bud bearing little or no wood to the surface of the growing wood of the stock. The bud is applied directly to the cambium layer of the stock." Budding is employed especially with young plants where the stock is one or two years old. The limbs from which the buds are to be used are taken from the current year's growth. Budding may be done about June, or as soon as the bark slips or peels easily. A T-shaped incision is made in the stock about 2 or 3 inches above the surface of the ground. The bud is cut and inserted into the incision, and tied with a soft string or raffia. After ten to fourteen days it should be examined. If it is living, it will be green and show signs of growth. The string may then be cut. The following spring the main trunk of the stock should be cut off about one third or one half of an inch above the growing bud, which will then grow rapidly, for all the growing energy of the plant will be forced into it. In one year the plants may be transplanted into the permanent orchard.

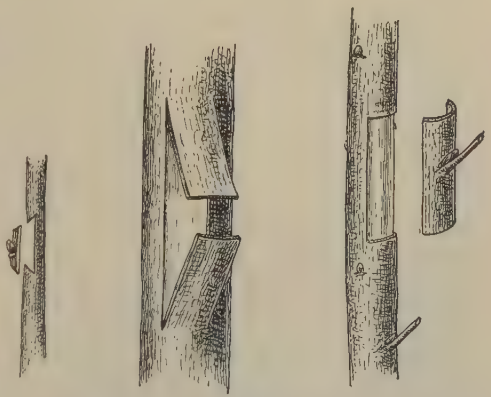


Fig. 192. — Three kinds of budding
At left, chip budding; in middle, H-budding; at right, flute budding.

[1] "The Nursery Book."

There are several methods of budding. The shield, plate, chip, and tubular methods are the ones most commonly employed. (See Fig. 192.)

All the methods of budding are based upon the same general principle; namely, that the cambium layer of the bark of the scion must fit and meet the cambium layer of the stock. It is through the cambium layer that the plant foods of the scion are carried to the stock. This is an important principle to observe in all grafting and budding work. From one thousand to two thousand buds can be set by an expert budder in a day.

Methods of scion grafting. — There are essentially two methods of scion grafting: the whip, or tongue, graft and the cleft graft. There are three positions of making grafts: (1) Grafts made on roots are called root grafts. (2) Grafts made on stocks just above the surface of the soil are called crown grafts. (3) Grafts made in the tops of trees are called top grafts.

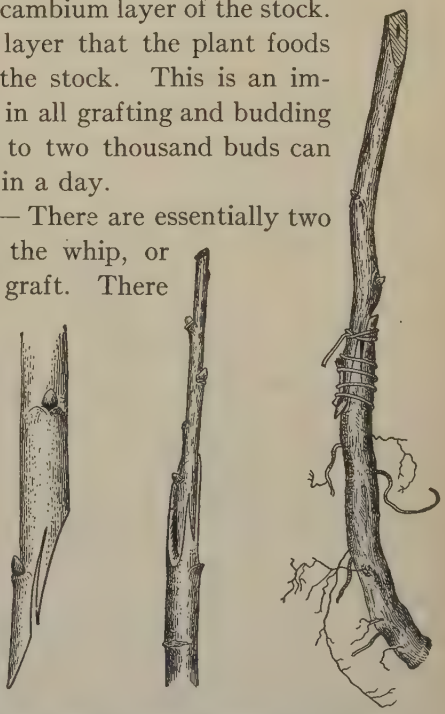


Fig. 193. — Whip grafting on stocks and roots

At left, scion of whip graft; in middle, whip graft in position; at right, root graft.

Root and crown grafts are employed in grafting scions on stocks one or two years old. The whip, or tongue, method is generally employed in root and crown grafts. Top grafting is used in grafting scions upon tops of old trees. The cleft graft is used almost wholly in top grafting.

Whip grafting. — Stocks of one year's growth are used in whip grafting. Seeds are planted in rows four feet apart in early spring. The seedlings are cultivated during the summer, dug up after the leaves have fallen off, and stored in convenient bundles in a cool cellar.

The desired variety of scions is also cut in late fall and stored in bundles of fifty or one hundred each in places similar to those used in storing the stock. Grafting may be done in January or February. This is a convenient time for making grafts for two reasons: (1) The stock and scion become somewhat calloused during the winter. (2) January and February are not busy months.

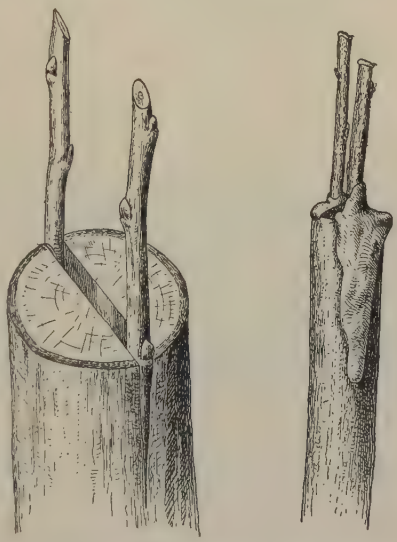


Fig. 194. — Cleft grafting and a waxed stub

It will be observed that Fig. 193 shows a root graft. Crown grafts are made in the same way except that the stocks are not cut so close, and the graft meets at a point on the stock just at the base of the trunk.

Cleft grafting. — In top grafting, the following points should be observed: (1) The scion should be cut very smoothly and should be from 4 to 6 inches long above the stock. (2) The lowest bud should stand just at the point shown in Fig. 194. (3) The stock having a large area of exposed surface should be well covered with grafting wax to avoid decay. (4) Top grafts are made in early

spring at about the time when trees begin to grow. The scions used should be entirely dormant, due to having been stored.

Note. — Grafting wax has the following formula:

Common rosin	5 parts
Beeswax	2 parts
Beef tallow	1 part

Summary. — Plants are multiplied by seeding, by layering, by cuttings, and by grafting, depending on the kind of plants. The increase of plants and the kinds of plants multiplied may be largely controlled by the selective power of man.

LABORATORY EXERCISES AND HOME PROJECTS

1. Study the parts of apple, pear, and cherry blossoms, all of which are perfect flowers. A dictionary or a botany textbook may be used as a reference. These will show names of the parts of the flower. Draw the flower and the parts of the flower in your notebook.

2. Bring to school three or more kinds of seeds which have special devices which aid them in their dissemination. Paste or draw these seeds in your notebook, and briefly describe how each may be disseminated. The written part may be made a language lesson.

3. Have pupils attempt to propagate plants by the system of layering. Have them report the following year.

4. Have pupils prepare or bring a propagating box and propagate some stem cuttings as described in the text.

5. If there is a nurseryman in the neighborhood, have him come in, or visit his place with the class in agriculture, and let him give a lesson on plant propagation. Pupils should make a written report.

6. Have demonstrations of whip and cleft grafting.

7. To make grafting wax, break or pulverize into small particles one pound of beef tallow, two pounds of beeswax, and five pounds of rosin. Stir the mixture thoroughly while melting. Let it cool after it is well mixed. Smaller proportionate quantities of the above ingredients may be used.

CHAPTER XXXII

VEGETABLE GARDENING

Importance of vegetable gardening. — Vegetables furnish a large part of the food used by the people of the United States. The total value of vegetables grown for home use, excluding white and sweet potatoes, in 1919 was $344,665,728. The average value of vegetables grown per farm was $68.

Courtesy of New Jersey Experiment Station

Fig. 195. — Effect of fertilizer on spinach

At the left, unfertilized; yield, 198 crates per acre; at the right, 1600 pounds of a 9-8-3 fertilizer used at planting; yield, 507 crates per acre.

There are also large truck farms that produce vegetables for sale. As the proportion of our population living in towns and cities increases, the amount of vegetables grown for market also increases. In 1919 the total value of vegetables grown for sale,

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: boards and sash for making a hotbed (may be used to start plants for the gardens of the patrons); some samples of fruit (five of a kind make a sample).

exclusive of white and sweet potatoes, was $193,258,964. The average value per acre of vegetables raised was $131. The states producing the greatest value of market vegetables, in the order of their importance, are California, New York, Florida, New Jersey, Ohio, Maryland, Pennsylvania, Massachusetts, Texas, and Michigan. Market gardening and truck farming provide a livelihood for a great many people in and around the large cities.

1. Fresh, home-grown vegetables furnish excellent food. All vegetables contain starches, fats, protein substances, ash, and water. All of these substances nourish the body or aid in digestion.

Composition of Some Vegetables

Food Materials	Water (Per cent)	Protein (Per cent)	Fat (Per cent)	Carbohydrates (Per cent)	Heat Value in a Pound (Calories)
Butter (for comparison)	11.0	1.0	85.0	0.0	3490
Peas	9.5	24.6	1.0	62.0	1610
Beans	12.6	22.5	1.8	59.6	1565
Tomatoes	94.3	0.9	0.4	3.9	80
Potatoes	78.3	2.2	0.1	18.4	380

Vegetables do not have the heat-producing capacity that meats and animal products have, and therefore they may be eaten to advantage in summer in order to keep down the body temperature. The amount of heat produced in the body by food is measured in calories. A pound of tomatoes furnishes only 80 calories, while a pound of butter furnishes 3490 calories.

2. The home garden reduces the cost of living. Vegetables, when purchased, are fairly high priced. A small bunch of radishes, lettuce, onions, or celery sells for 5 to 10 cents or more.

3. The garden is an excellent laboratory in which to learn something about soil, soil management, and how to keep up the

fertility of the soil. The growing of plants and the management of hotbeds and cold frames are helpful studies. The origin, history, and development of vegetables is an interesting field for investigation.

4. Another reason why every home should have a garden is that the garden yields about ten times as much food as a similar area will under general farm practice. A half-acre planted to vegetables will yield from twelve to fifteen times as much food as when planted to corn or wheat.

5. Vegetables furnish an abundance of vitamins, food compounds absolutely essential to health and life. Some of the dry foods and cereals we use are strikingly lacking in vitamins. Whole milk is good in its vitamin content. The following table brings out the comparison. The chemical composition of vitamins is unknown, and therefore the four-plus system is used to show the comparative amounts of each of the vitamins in each food. Four plus signs represent a best source; three plus signs, a good source; two plus signs, a fair source; one plus sign, a source.

VITAMINS IN FOODSTUFFS

	VITAMIN A FAT-SOLUBLE	VITAMIN B WATER-SOLUBLE	VITAMIN C ANTISCORBUTIC
Whole milk	+++	+++	++
Skim milk	o	+	+
Wheat flour	o	o	o
Lettuce	++	++	++++
Spinach	+++	+++	+++
Celery	o	+++	++
Beets	+	+	+
Cabbage	++	+	+++
Cooked cabbage	o	+	+
Potatoes	o	o	++
Oranges	o	+++	++++
Lemons	o	+++	++++

It may be seen that vegetables contain an abundance of vitamins, and therefore they protect against certain diseases which occur when the vitamins are lacking. Vitamin A produces growth and prevents an eye disease known as xerophthalmia. Butter fat and cod-liver oil contain an abundance of fat-soluble A, and hence become important as medicine or food in the prevention and cure of this disease. The lack of vitamin B causes a disease known as

From McCollum's Newer Knowledge of Nutrition

Fig. 196. — Rats fed on different kinds of fats

"The rations of these two rats from weaning time were exactly alike except in the character of the fat which they contained. The one on the left was given 5 per cent of sunflower seed oil. The one on the right was given 1.5 per cent of butter fat. Butter fat, egg yolk fats and the leaves of plants contain a dietary essential, the chemical nature of which is still unknown, which is necessary for growth or the maintenance of health. This substance is known as fat-soluble A, and is not found in any fats or oils of vegetable origin. A lack of this substance in the diet causes the development of a peculiar eye disease known as xerophthalmia. The animals were the same age when photographed."

beriberi. The symptoms of this disease are paralysis, a skin trouble of the extremities, nervousness, and dropsy. Vegetables and fruits furnish vitamin B, which is a preventive and remedy for this disease. Vitamin C, known as the antiscorbutic vitamin, prevents scurvy. This disease is characterized by bleeding from the gums, mouth, and nose, swelling of the gums and tongue, discoloration of the skin, and depression of spirits. Lemon or orange juice and limewater are recommended as a preventive of these conditions. Other fruits and vegetables are also rich in

vitamin C and are highly beneficial in furnishing a part of the nutrients of a well-balanced ration.

Elements of success in gardening. — Successful gardening depends upon several important factors: (1) The soil should be a well-drained, dark, rich, sandy loam. (2) If an early garden is desired, the soil should be a sandy loam on a southern slope. (3) The soil should be plowed or spaded deep the preceding fall. (4) The garden must be thoroughly cultivated. (5) Good seeds must be planted. (6) A good soil mulch must be maintained in order to conserve the soil moisture. Paths in gardens violate all principles of good farm practice, because paths usually contain large cracks, through which the soil moisture escapes.

Garden products for the entire year. — Gardens should be planted so that vegetables will be ready for table use the entire year. No exact dates can be given to cover this topic. Canning some vegetables and storing others must be resorted to if the garden is to be a 365-day garden.

EARLY SPRING VEGETABLES:		
	Lettuce	Rhubarb
	Radishes	Strawberries
	Onions	Cabbages
	Peas	Mustard
SUMMER VEGETABLES:		
	Potatoes	Beans
	Tomatoes	Sweet corn
	Beets	Celery

These vegetables can be used until late fall or early winter. Can tomatoes, sweet corn, and strawberries for winter use. Store turnips, sweet potatoes, Irish potatoes, and onions. A well-planned garden partially supplies the table daily the year round.

Construction and use of hotbeds. — Hotbeds may be made any size according to the size of the glass available. A convenient

size is three by six feet. A pit 18 inches deep should be dug and filled with about 12 inches of half-decomposed horse manure, well packed. Manure composed of about one-half wheat straw is better, for fermentation will go on more rapidly. Cover this with 6 inches of good soil. Make the top so that the glass cover slants

From Watts' Vegetable Growing Projects

Fig. 197. — A cold frame with a forcing crop

toward the south. A cold frame is made like a hotbed except that it is built on top of the soil. Hotbeds and cold frames are usually built on the south side of a building so as to get the greatest heat from the sun.

Hotbeds are used for starting lettuce, radishes, tomatoes, cabbage, and other plants. After plants are well started in the hotbeds, they should be transplanted into cold frames, where they become hardened. Hotbeds and cold frames should be

maintained at a uniform temperature if the best results are to be obtained, and they should be protected from extremes of sunshine and cold.

Plan of the garden. — A long narrow garden is more easily tilled than a square one of the same size. A large garden can be cultivated with horse power. Vegetables should be planted the long way of the garden, and each row should extend from one end to the other. If the rows are planted 18 inches apart, a hand plow can be used to advantage. If a horse is to be used in cultivating, the rows should be at least 24 inches apart.

The vegetables should be arranged when planted so the planting can be started at one side of the garden and continued until the entire garden is planted.

Lettuce. — Lettuce is grown for a salad plant more extensively than any other vegetable. Crisp, fresh lettuce is an excellent food for early summer and is therefore an important crop for truck growers and gardeners. Lettuce is adaptable to a wide range of climatic conditions and, with proper cultivation, will grow in almost every section of the United States the year round. In the South it is grown in the garden throughout the year. In the North it is grown under field conditions in early spring, summer, and fall, and during the winter as a forced crop in greenhouses.

Lettuce plants are started in hotbeds by sowing the seeds in rows 3 or 4 inches apart, and covering them with a half-inch of soil. After the plants are large enough, they are transplanted into the cold frame and, later, into the garden. Frequent cultivation is essential to hasten the growth of lettuce.

Mildew and rot are the most common diseases of lettuce and are caused by wet, hot conditions. Especial care should be taken in watering lettuce to keep the water from coming

in contact with the leaves of the plant. Sub-irrigation is usually employed in forcing lettuce.

Navy beans, grown both in the garden and in the field, have become an important crop, because they grow on almost any type of soil, bringing good yields, and they provide solid nourishment equal to almost any other garden product.

Preparation of soil. — Fall plowing with a cover crop of rye, the rye being plowed under about May 1, is a good way of preparing the seed bed. The soil should be plowed six to eight inches deep and then compacted with a harrow. A good earth mulch should be maintained in order that the maximum amount of moisture may be conserved.

Planting. — Navy beans are planted rather late, about June 15 to 30 for Missouri conditions. They are planted late so that all pods will mature at about the same time, and just as late in the fall as possible. This will avoid trouble caused by the bean weevil. If grown in a field where they are to be cultivated by machinery, they may be planted about twenty-eight to thirty-two inches apart between the rows and from three to five inches apart in the row.

Cultivation. — If the seed bed is well prepared, only shallow cultivations are needed. The purpose in cultivation is to keep the weeds down and to preserve a soil mulch to prevent the escape of soil moisture. Narrow-toothed implements are most suitable for cultivating navy beans. The depth of cultivation need not exceed two to three inches. Beans should not be cultivated when there is dew or moisture on them.

Harvesting. — Where navy beans are grown on a small scale, they are pulled up by hand when ripe. And as soon as they become dry enough, they may be placed in a small box and tramped out. When grown on a large scale, the bean harvester and a bean huller are used in harvesting. A threshing machine

is sometimes used by removing the concave and some of the teeth of the cylinder. One of the difficult points in threshing is the avoidance of cracking the beans while threshing. When beans are very dry, they crack and split quite readily, and for that reason beans are most satisfactorily threshed when not so very dry.

Uses of navy beans. — Navy beans will yield under average conditions from ten to twelve bushels per acre, and under good conditions may yield fifteen to twenty-eight bushels per acre. Navy beans have a high protein composition and are excellent food for growing children or for hard-working people. Navy beans are very nutritious and they have a high percentage of dry content (p. 386).

Beets. — Beets are hardy and are very widely distributed. They are grown mostly for winter use, and therefore the roots are permitted to grow as large as possible. The soil best suited for beet production is a rich sandy-loam soil; a soil that has been well manured and warms up quickly in the spring is most congenial to beet production. Deep fall plowing to a depth of eight to ten inches is recommended. Well-rotted barnyard manure at the rate of twenty to twenty-five tons per acre will help to increase the yields.

Tomatoes. — Tomatoes are of American origin. They were carried to Europe from Peru. For a long time tomatoes were thought to be poisonous; they were used only for ornament, and were called "Love Apples." After the notion that they were poisonous disappeared, their use for food grew rapidly, and to-day tomatoes are of considerable commercial importance. They are an important food because of the protein, sugar, ash, and vitamin content, and because the acid in them aids digestion.

Culture. — Tomatoes are started in hotbeds in early spring. They require 100 to 140 days for their maturity, and therefore must be started early. Transplanting into the permanent garden

should be done when the season is fairly sure, and when the plants have from 6 to 8 leaves. Plants must be set deeply and the soil packed firmly about them. This precaution in setting out plants will aid much in keeping them alive. Where tomatoes are hand tilled, they may be set 3 to 4 feet apart each way, depending on the variety.

Courtesy of U. S. Department of Agriculture

Fig. 198. — Pruned and staked tomato vines

If the seed bed for the plants is well prepared, little other than surface cultivation is needed to keep down the weeds and conserve the moisture.

Another important phase of tomato culture, if the best results are to be secured, is proper staking and pruning. Since they are susceptible to fungous diseases, they need much air and sunshine. They should be staked and tied to the stakes (Fig. 198). All suckers growing in the lateral axils should be removed.

Varieties. — For early use, the Earlianna, Bonnie Best, Early Jewell, and June Pink should be planted; for late use, the Ponderosa, Stone, Acme, Matchless, Trophy, and Beauty.

Fertilizers. — Since tomatoes are grown for their fruit, fertilizers may be used to increase the yield. Potash and phosphoric acid fertilizers supply the needs of fruit; and nitrogen fertilizers stimulate vegetative growth. Stable manures are not often used as fertilizers for tomatoes, because they cause an excessive growth of the plant and hinder fruiting. Fertilizers in which the plant foods are readily available to the growing tomato plants should be used.

Spraying. — Tomatoes are subject to a fungous disease called leaf spot which turns the leaves yellow in spots, dries them up, and kills them. The disease spreads rapidly from leaf to leaf and from plant to plant. When leaf spot appears, the plants should be thoroughly sprayed with Bordeaux mixture. They should be sprayed several times at intervals of 8 to 10 days, depending upon conditions. Wet, hot weather promotes the growth of leaf spot.

Radishes. — Although they are adapted to a wide range of climatic conditions, radishes do best in early spring and fall when the temperature is moderately warm. If they are to have the best flavor and the proper crispness of texture, they must be grown quickly. A slow growth causes them to have an unpleasant, acrid flavor and a tough, fibrous texture.

Culture. — When radishes are grown alone, they are sown in rows 12 to 18 inches apart, one-half to one inch deep. The soil should be what is called a "quick soil," composed of sand, clay, and humus. A "quick soil" can be tilled soon after a rain, because it is porous, permitting the rapid escape of free water and because the black color, caused by the humus, absorbs the sun's rays and warms it quickly.

Radishes are often grown as one of a "succession crop," between two rows of lettuce. On each side of these three rows is grown a row of Irish potatoes, cabbage, peas, beans, or sweet

corn. A continuous supply of radishes may be had by sowing seeds at successive intervals of about ten days. If radishes are to be sold on the market, they should be tied in bunches of five or six radishes. The tops are left on, because they protect the radishes to some extent.

From Watts' Vegetable Growing Projects

Fig. 199. — Good specimens of oblong radishes

Garden peas. — Peas require a warm, quick soil, if they are grown in early spring. A rich, friable, well-drained soil is desirable for their early development. The dwarf and early-maturing varieties, such as the Alaska and American Wonder, should be planted early. They may be planted from 3 to 6 inches apart in rows from 15 to 18 inches apart. If peas are wanted for midsummer, larger and later-maturing varieties, Telephone, White

Marrow, Fat, and Pride of the Market, should be planted. Vining peas may be trained to grow on poultry wire netting. Three-foot netting makes a satisfactory trellis.

Peas as food. — Peas, like beans, have hardly an equal as food. They are rich not only in protein substances, but in the other nutrients (p. 386), and have an excellent flavor.

Beans. — The culture of garden beans is like that of peas, except that beans require a warmer temperature and therefore must be planted later. For early-maturing varieties, early dwarf or bunch beans should be planted, such as Red and White Kidney beans. For later-maturing varieties, pole beans, such as the vining Lima and the Kentucky Wonder, should be selected.

Cabbage. — Cabbage is a favorite garden vegetable throughout the United States, and in some sections it is grown extensively as a commercial crop. The tonnage produced per acre is large and the price generally low, but the sale of cabbage is assured because of its wide use. Cabbage requires a great deal of moisture for its growth, and for this reason it may be planted in a soil that contains more than an average amount of moisture. There is an old saying that "cabbage should be hoed every day." This is almost true, for frequent cultivation maintains an earth mulch which conserves the soil moisture.

Cabbage requires an abundance of plant foods rich in potash and phosphorus. Stable manure may be applied, but, in addition, either acid phosphate at the rate of 750 pounds per acre or muriate of potash at the rate of 500 pounds per acre will help production. A fertilizer composed of nitrogen 2 per cent, phosphoric acid 6 to 8 per cent, and potash 8 to 10 per cent is usually satisfactory. About 1200 to 1800 pounds per acre should be applied.

Varieties. — Early Jersey Wakefield and Henderson's Early Summer are early varieties; the Flat Dutch, Stone Mason, and

Autumn King are later-maturing varieties. Each of these varieties has been developed with flat, conical, or spherical heads. Different markets demand differently shaped heads. Catering to the demands of the market is a part of good gardening.

Enemies of cabbage. — Probably the worst insect enemy of cabbage is the cabbage worm. It is an inch to an inch and a half long and has a green velvety appearance and a faint yellow stripe down the middle line of the back. The larvæ, which develop into "cabbage butterflies," eat irregular holes in the leaves and disfigure the heads of the plants with deposits of excrement. "Arsenicals may be used safely on cabbage until they are half-grown. Hellebore may be used on plants ready for market." [1]

Fig. 200. — Cabbage butterfly

***a*, adult; *b*, eggs; *c*, larva; *d*, pupa, or chrysalis.**

Other insects injurious to cabbage are the flea beetle, root maggot, cutworm, and cabbage aphis. For their control write to your State Entomologist, who generally resides at the State College of Agriculture.

Summary. — Every home, not only in the country but also in the city, should have a vegetable garden. If the garden is carefully planned, vegetables may be had almost every day in the year. The cost of living may be reduced to a considerable

[1] O'Kane, "Injurious Insects."

extent even by a small garden. Vegetables are healthful as well as nutritious. They contain a high percentage of mineral matter and vitamins, which are absolutely essential in nutrition. The elements of success in gardening are a careful preparation of the seed bed, thorough cultivation, and the combating of vegetable enemies.

LABORATORY EXERCISES AND HOME PROJECTS

1. Have each pupil, with the help of his parents, figure the value of the products derived from his home garden. Have the pupils bring an itemized statement of the value of the different vegetables produced in the home garden. Discuss.

2. Have pupils discuss the methods used in storing, canning, or keeping ten garden vegetables.

3. If it is springtime, have pupils design and make a hotbed and start some lettuce, cabbage, and tomato plants. This exercise can also be done in the fall.

4. Have pupils plan the arrangement of vegetables for a garden one hundred by two hundred feet.

5. Score single-plate samples of tomatoes, potatoes, radishes, turnips, or any other suitable vegetables according to the following score card. (Five of a kind generally constitute a sample.)

SCORE CARD

	POINTS		SAMPLE SCORED		
Form	15				
Size	15				
Color	20				
Uniformity	20				
Freedom from blemishes	30				

Explanation of values:

Form (15) refers to the normal type and shape of the variety. For each specimen varying from the type, cut according to judgment.

Size (15). — The size most in demand by the market may be considered the best size. Oversized vegetables should be discouraged, but a size slightly above the average may be considered best. Apply score according to judgment.

Color (20). — The color should be uniform and show that all specimens of the sample belong to the same variety. Cut according to judgment.

Uniformity (20). — All points pertaining to size, color, shape, and texture are important. Cut according to judgment.

Freedom from blemishes (30). — Freedom from blemishes is essential to a good sample. Bruised places, decayed spots, and a diseased surface are objectionable. Cut according to judgment.

(Two or more days may be devoted to this lesson.)

6. Write the kinds and varieties of the vegetables grown in your home garden.

7. What are the five worst enemies of your vegetable garden? Write a paragraph about each, telling how you would combat it.

8. Have the boys write a story telling about the growing of any garden vegetable and have the girls write about the canning of some garden vegetable.

CHAPTER XXXIII

FRUIT GROWING

Importance of fruit. — According to the 1920 Census Report the value of fruit for 1919 was $703,284,587. This was about twice the value of the vegetable crop grown for home use. There is hardly a home, especially in the rural districts, that has not a few fruit trees. Apples, peaches, cherries, plums, and berries are so well liked that nearly every home owner should grow one or

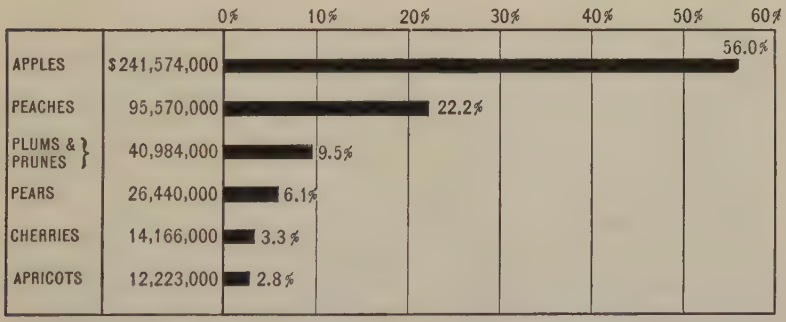


Fig. 201. — **Value of principal orchard fruits**

more of these fruits. The value and relative importance of the leading orchard fruits according to the 1920 Census Report are given in Fig. 201.

Note to the Teacher: The materials needed to do the Laboratory Exercises and Home Projects suggested at the close of this chapter are: several grasshoppers and bees; a glass jar; a cabbage worm; samples of apples, peaches, pears; scales.

1. The chemical composition of all fruits is such that they are not only nutritious but very valuable in aiding digestion. The composition of the edible parts of some of the fruits is given below:

Fruit	Protein (Per cent)	Carbohydrate (Per cent)	Fat (Per cent)	Total Solids (Per cent)	Water (Per cent)
Apples	0.4	14.2	0.5	15.1	84.6
Peaches	0.7	9.4	0.1	10.2	89.4
Cherries	1.0	16.7	0.8	18.5	80.9
Grapes	1.3	19.2	1.6	22.1	77.4

2. Most fruits contain also some acids which help to digest food and prevent constipation. An apple eaten before retiring has a helpful effect.

3. The third advantage of fruits is that they furnish vitamins (p. 387). It has been observed that the people who use fruits are strikingly free from certain diseases and, in general, enjoy good health. This condition is due to the vitamin content furnished by fruits.

Vitamins in Fruits

	Vitamin A Fat-soluble	Vitamin B Water-soluble	Vitamin C Antiscorbutic
Apples	o	++	++
Bananas	o	+	++
Grapes	o	+	+
Lemons	o	+++	++++
Oranges	o	+++	++++
Pears	o	++	++
Raisins	o	+	+
Tomatoes	++	+++	++++

Fruits lack vitamin A but are fairly rich in vitamin B, and almost perfect in vitamin C.

Soils adaptable to orcharding. — Almost all orchard trees feed deeper than does the average crop. For this reason a deep porous soil and subsoil are essential. A soil that is underlaid with hardpan is not adaptable to orcharding, but a gravelly or a sandy subsoil is not seriously objectionable. In fact, some of the most productive orchards are in regions that have a gravelly subsoil. A loose soil and subsoil allow free circulation of air, a condition essential to orcharding. An impervious subsoil holds the water, and few orchard plants thrive in such a condition.

Although orchards do moderately well on soils of low fertility, a soil that is fairly fertile is desirable. Soil drainage is more essential than soil fertility. Fertility may be increased, but an impervious soil can not be made porous.

Rich bottom lands seldom furnish good orchard soils. This is because fruit trees have a tendency to produce too much vegetative growth on such lands and to remain barren. Fairly fertile, porous, mellow uplands are best suited to fruit production.

Location of the orchard. — South slopes are warmer than north slopes and give more exposure to the sun, which is essential for producing highly colored fruits. North slopes are usually more fertile and do not warm up so easily in spring. A fruit crop is often saved because the orchard is on a north slope. A north slope often prevents sun scalds of the trunks of fruit trees. The best slope for an orchard depends somewhat on the climate.

Air drainage should also be taken into consideration in locating an orchard. Cool air is heavier than warm air and sinks to the lowest levels. For this reason frosts are more common during early spring and late fall in valleys than upon higher places. Occasionally a fruit crop is lost because the orchard is in a low valley.

The top of a hill is not a desirable location for orchards,

because (1) the trees are exposed too much to the winds which often break them, and (2) the fruit is blown off the trees where there is too much exposure. Both very low and very high places should be avoided in selecting an orchard site.

Photo by Cook

Fig. 202. — Orchard in bloom

A slope or an elevated valley offers an ideal location for fruit trees.

Preparation of the soil. — The soils in which orchards are to be planted should be prepared as for the sowing of wheat or planting of corn. If the soil is to be cropped the preceding summer, soy beans or cowpeas may be used to improve the soil both physically and chemically. Soy beans are a fine crop to precede the planting of an orchard. The soil should be plowed deeply and worked down so that its tilth is good. The ground

may be harrowed occasionally to keep down the weeds and to keep an earth mulch which helps to conserve the moisture.

Planting fruit trees. — How far apart trees should be set depends upon the kind of tree and the fertility of the soil. The following table is suggestive:

Apples	25 to 30 feet each way
Pears	20 feet each way
Peaches	20 feet each way
Plums	20 feet each way
Cherries	18 feet each way
Grapes	6 feet by 8 feet

Trees should be set in the orchard at about the depth to which they were planted in the nursery. Before setting a tree, all bruised and broken roots should be removed with a sharp knife, and the top should be cut back as indicated in Fig. 203. In trimming a tree it is well to remember that the tops can not grow a root system, but that a good root system can grow a top.

In moving, trees should not be permitted to lie in the sun and wind, for this soon destroys their vitality. The violation of this rule and poor setting kill more trees than all other factors combined. The most important point in setting trees is to pack the loose soil around the roots firmly. Tramping the soil around the roots is a good practice. After a small amount of soil is shoveled around the roots, it should be packed; then more soil should be added and packed again. The top two or three inches should be left in the form of a loose mulch.

Tillage of orchards. — Cultivation of orchard crops is neglected more than that of any other farm crop. If cornfields were permitted to grow up in hay and weeds such as are often seen in orchards, it would be quite reasonable to expect small returns. Likewise the returns from untilled orchards are short. Young orchards should be kept free from weeds, but tilled

crops, cowpeas, soy beans, corn, strawberries and other plants may be grown to advantage. In cultivating orchards care should be taken not to bark the growing trees, because the bruises bring on disease. Orchards should not be cultivated after the latter part of July or the early part of August. A cover

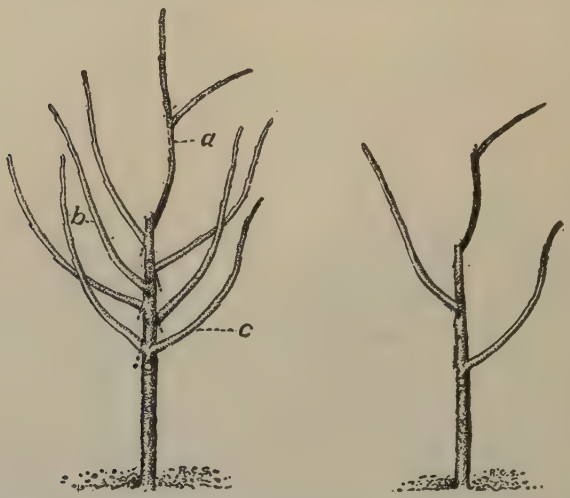


Fig. 203. — **A one-year-old apple tree before and after pruning**
Dotted line shows where to cut; three scaffold branches, *a*, *b*, and *c*, are left.

crop of rye or wheat may be sown in September. This protects the soil for the winter. Occasionally a green cover crop of soy beans or cowpeas is plowed under to maintain the organic content of the soil. Exceedingly steep orchard lands should not be cultivated.

Pruning trees. — Most fruit trees need pruning. There are three main reasons for pruning trees: (1) to control the size and shape of the top; (2) to remove dead branches; and (3) to stimulate and promote either vegetative growth or fruitfulness.

1. Trees should be pruned to a pyramidal shape, or an open vase form. Forked trees are undesirable. (See Fig. 203.) The tree may be pruned when young so that the head of the tree

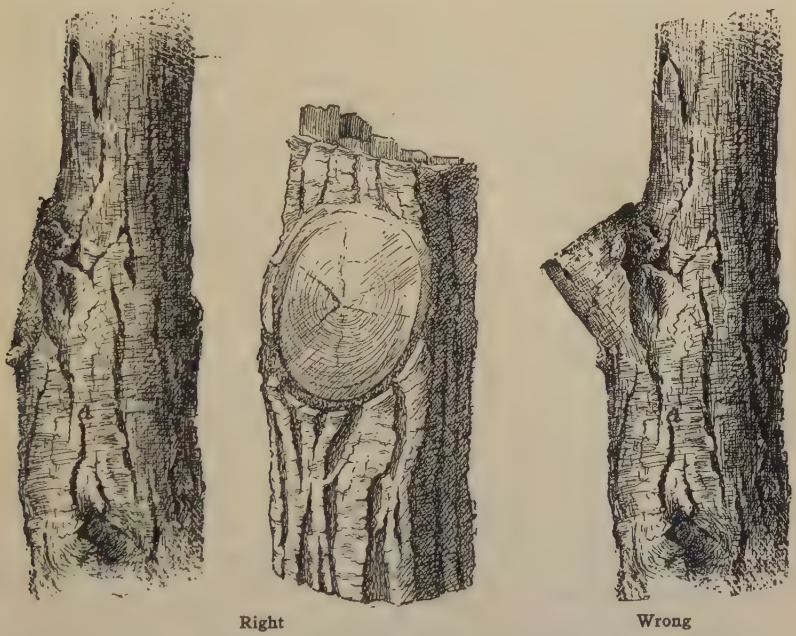


Fig. 204. — Right and wrong way of pruning

The part of the limb left on the tree (at the right) offers an opportunity for decay and entrance of fungous growths.

is near the ground. This method has some important advantages: (1) The trunk of the tree will be protected from the sun, and sun scald prevented. (2) The work of gathering, spraying, and pruning can be done more easily and cheaply. (3) Trees are not so easily wind-broken.

2. All dead branches should be removed. Water shoots and other limbs that tend to crowd the top should be pruned out in

order that all the strength of the tree may go into the growth of the desirable limbs or fruit.

3. To promote vegetative growth, trees should be pruned in winter. But if they grow too vigorously, they should be pruned in summer. This checks vegetative growth and causes the additional plant food to form buds. These fruit buds are formed in June and July of the summer preceding the bearing season. If pruning is employed to stimulate fruit production, it should be done about the first of June.

Fruit buds are borne upon short limbs called "spurs," which occur on wood one year old or more. Heading in or cutting the limbs back should be done with care, lest the bearing wood be decreased to such an extent that the fruit crop may be greatly curtailed. In pruning, the limbs should be cut so that the wound will heal over quickly. Limbs should be cut near the trunk or near the limbs from which they branch.

Origin and development of the apple. — Apples originated in southeastern Europe or southwestern Asia. The wild crab is claimed to be the original from which came our domestic apples. The wild crab even to-day will readily hybridize, or cross, with our domestic varieties. Apple twigs may be budded, or grafted, on root stocks of the wild crab, and vice versa. This shows the close relationship between the domestic apple and the wild crab.

Recommended Varieties of Apples

Summer	Fall	Winter
Red June	Wealthy	Gano
Yellow Transparent	Grimes Golden	Ingram
Red Astrachan	Jonathan	Delicious
Early Harvest	Huntsman Favorite	York Imperial
Maiden Blush		Stayman Winesap

Varieties. — Care should be exercised, in choosing varieties for the home orchard, to select only such varieties as are known to do well in the locality. If an orchard is planted for commercial purposes, the "market demands" should also be considered. For family use, it is good practice to plant some summer, some fall, and some winter apples.

Fig. 205. — Mouth parts of a beetle

Insect enemies. — From the standpoint of control there are two kinds of insects: (1) Those that secure their food by chewing; (2) those that secure their food by sucking. The insects belonging to the first group get their food by biting off parts of the vegetation. They have a pair of jaws intended for chewing or biting. If we examine a grasshopper or a beetle, we shall find that it possesses a pair of biting instruments called mandibles. But if we examine a butterfly, a moth, or a bee, we find no jaws or parts that may be used to bite or to chew. Instead we find a long tube (proboscis) through which the insect sucks its food. Some of the enemies of the orchard belong to the first group; others to the second.

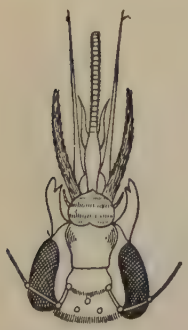


Fig. 206. — Mouth parts of a honeybee

The methods for controlling are different. O'Kane says: "Insects with biting mouth parts may be killed by covering the plant on which they feed with a poison such as lead arsenate. Insects with sucking mouth parts do not eat the surface of the plant and can not be killed by applications of stomach poison.

For the latter, other remedies must be used — some substance that will kill the insect by corrosive action on its body."[1] These remedies are usually called contact insecticides, such as kerosene emulsions or lime-sulphur wash.

Codling moth. — The adult codling moth lays its eggs on the calyx of the apple blossom. In a few days the eggs hatch and the larva enters the young fruit through the calyx end. The larva feeds on the inside of the apple (Fig. 207).

The mature larva comes out of the apple, finds a suitable shelter for the winter, and spins its cocoon. Since the worm

Fig. 207. — Life history of the codling moth

a, egg; *b*, larva; *c*, pupa; *d*, adult (all greatly enlarged).

gets its food by biting, one must spray just before apple blossoms bloom and again just after the blossoms have fallen. The second spraying is more important. A third spraying should be given three weeks later. A solution made by dissolving two pounds of arsenate of lead in fifty gallons of water, or by mixing four ounces of Paris green in fifty gallons of water should be used.

San José scale. — The San José scale is among the worst insect enemies of orchards. It attacks all kinds of vegetation and in a few seasons may kill peach or plum trees. Apple trees, being more hardy, withstand its ravages a little longer.

This scale is a sucking insect, and a contact insecticide must

[1] O'Kane, "Injurious Insects"

be used in combating it. Such an insecticide may be either of the following:

HOMEMADE CONCENTRATED LIME-SULPHUR

Lump lime	60 pounds
Sulphur	125 pounds
Water	50 gallons

This spray should be made by first mixing the sulphur with the water and then adding the lime.

KEROSENE EMULSION

Hard soap	½ pound
Hot water	1 gallon
Kerosene	2 gallons

Trees should be treated before the vegetation appears. O'Kane says: "The best time for application is in the spring just before the buds swell. Where the infection is severe it is well to spray in the fall after the leaves have dropped and again in the spring."[1]

Apple scab. — This fungous disease of apples attacks both fruit and foliage. It thrives best in moist, cool weather. Scab disfigures and distorts the fruit by preventing growth where it occurs. A prevention and a remedy for apple scab is found in the use of Bordeaux mixture (Fig. 221).

Fig. 208. — San José scale — a sucking insect

BORDEAUX MIXTURE

Copper sulphate	4 pounds
Lime	4 pounds
Water	50 gallons

Trees should be sprayed just before blooms open, and again after the blooms are off, and a third time when the apples are

[1] O'Kane, "Injurious Insects."

about half-grown. This will control the apple scab, rot, and mildew.

Borers. — There are two kinds of borers that attack apple trees, the round-headed borer and the flat-headed borer. The round-headed borer bores under the bark just beneath the surface or slightly above the surface of the ground. The flat-headed

Courtesy of International Harvester Co.

Fig. 209. — A power sprayer at work
Dormant spray is applied to the trees in the winter time.

borer works about three feet above the surface of the ground. Both are killed in the same manner. A knife should be used to find the openings made by the worm, and then a wire inserted into every opening will probably destroy the borers if every portion of the opening is penetrated.

Culture of peaches. — Peaches demand a fairly dry, porous soil, and will not thrive in a wet, compact soil. The subsoil should

also be porous. Clean cultivation is recommended for peach orchards. A by-crop such as potatoes, strawberries, or currants may be grown with the peaches. Spring planting is preferable. The trees should be planted about twenty feet apart and as deep as they stood in the nursery.

Varieties. — The following is a suggestive list of peaches classified according to the seasons in which they mature:

Summer	Fall
Carmen	Heath
Champion	Beauty
Sneed	Iron Mountain
Elberta	Krummel October
Crosby	

Enemies of peaches. — *Leaf curl*, due to a fungous growth, disfigures the leaves, which often grow twice their normal size. The preventive is to spray with Bordeaux mixture just before the buds open.

Brown rot is a soft rot which destroys the peach fruit, just a few days before maturity. It is most prevalent during hot, wet weather. There is no cure for brown rot. Spraying trees with self-boiled lime just after the blossoms have fallen, and again three or four weeks later, will control it somewhat.

Peach scab causes large blotches on peaches, and often causes them to crack open. The treatment for scab is the same as for brown rot.

The *plum curculio* ruins peaches by its stings and scatters the brown rot. If the curculio is controlled, the brown rot disappears (Fig. 210). To combat the plum curculio, one should spray with arsenate of lead, using the following composition:

Arsenate of lead	1½ pounds
Lime	2 pounds
Water	50 gallons

The spray should be used the first time when the calyx tubes are falling off, and again three weeks later. If needed, a third spraying may be applied.

Fig. 210. — **Plum curculio**

a, **larva in the fruit;** *b*, **fruit showing punctures;** *c*, **larva and pupa;** *d*, **adults.**

Plums. — Plums thrive best in moist places, on north slopes, and along streams. A classification of plums in the order of their maturity follows:

American Plum Varieties:

Milton	Wild Goose
Robinson	Newman
Forest	Wayland
Missouri Apricot	

Japanese Plum Varieties:

Abundance	Burbank	Chabot

European Plum Varieties:

Green Gage	German Prune
Lombard	Shropshire Damson

The principles of spraying suggested above apply to spraying for the enemies of plums.

Cherries. — Cherries grow best in a medium-dry, porous, well-drained soil. After the third or fourth year, there is little need for cultivation. If they are cultivated after this, the tillage should be very shallow, because the roots of cherries grow very near the surface of the soil. The best varieties are:

Early Richmond
Wragg
Montmorency
English Morello

© *Keystone View Co.*

Fig. 211. — Domesticated grapes
All our cultivated grapes are descended from the American wild grape.

Cherries and plums are liable to be destroyed by the fruit-rot fungus if they are left on the trees until they are ripe. It is therefore important that these fruits be picked early.

Grapes. — There should be grapes in every orchard. They furnish an excellent arbor, are safe bearers, and provide a good fruit. A well-drained but moist soil is best adapted to grape production.

Grapes are propagated by cuttings and layerings. Layers or cuttings may be planted in the permanent place or orchard when two years old. The vines should be trained to grow on a two- or three-wire trellis. They may be expected to bear when three or four years old.

In pruning grapes, three buds are ordinarily left on each branch. Dead wood should be removed.

Varieties. — The common standard varieties of grapes are the following:

Green Mountain — an early white grape.
Moore's Early — an early black grape.
Moore's Diamond — a white grape.
Worden — a large black grape.
Concord — the old standard black grape.
Wyoming Red — a small red grape.

Enemies of grapes. — Black rot is the worst disease of grapes. It causes small black spots on the fruit. To combat black rot one should spray with Bordeaux mixture. The first spray should be applied when the third leaf appears; the second before the blooms open; the third after blooming, and again two or three weeks later.

Summary. — Fruit growing is important in every section of the United States, and some fruit is found on almost every farm. Fruit growing is fairly successful in most sections, but better results would be secured if proper attention were given to it. Orchards are too frequently neglected. If an equal time were given to our orchards as is given to other crops, the results would be more satisfactory.

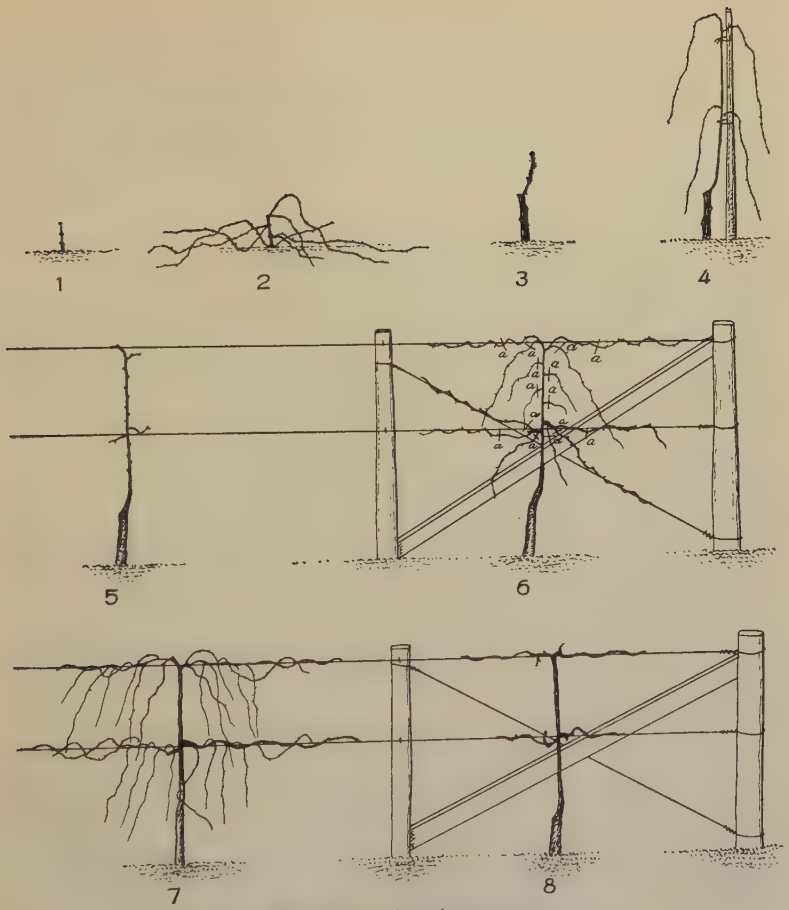


Fig. 212. — Pruning grapes

1, a young grape plant pruned to only three buds; 2, plant at the end of the first season; 3, plant pruned at the end of the first season; 4, during the second season only one cone is allowed to develop. The top of the cone is pinched off to induce shoots to form and only four of these shoots are allowed to grow; 5, pruning at the end of the second season; 6, growth during the third season. Some fruit can be expected the third year. The amount of pruning necessary and places to make the cuts are indicated by the marks across the canes at *a*; 7, mature grape vine, trained to the four-arm Kniffin system; 8, vine after being properly pruned.

Selection of the orchard site, cultivation, and combating enemies are essential to success. Proper spraying is necessary if good sound fruit is to be secured. Quality and freedom from blemishes are the first considerations of the market in the purchase of fruits.

LABORATORY EXERCISES AND HOME PROJECTS

1. With the help of every pupil in school, take a census of the number of apple, peach, cherry, plum, and pear trees in the school district.

2. Discuss orchard sites, using the five best orchards in the district as examples.

3. Observe the practice with reference to pruning in at least two orchards. Describe and discuss each.

4. Name, according to seasonal maturity, at least ten varieties of apples found in your neighborhood.

5. Bring to school a large grasshopper and study its parts. Examine the mouth parts carefully and draw them. Write a brief discussion, stating how you would combat insects with similar mouth parts.

6. Bring to school a bee, or any other insect having sucking mouth parts, and carefully examine its mouth parts. Draw and describe what you find. Write a brief discussion, stating how you would combat insects with similar mouth parts.

7. Bring a worm found in an apple to the school, and place in a large glass bottle or jar. Place a worm-eaten apple in the jar with the worm. From three to six weeks may be required to note changes in the transformation of the worm. A cabbage worm may be used in this exercise. Whatever insect is used, proper feed should be provided. Draw the stages of the life history of one insect. Look up the terms "larva" and "pupa."

8. Score several samples of fruit, using the general score card found at the close of the preceding chapter (p. 399).

9. Bring two apples to school; weigh the smaller one. Peel the larger and pare it down until its weight is the same as the weight of the other apple. Weigh apples on alternate days for about two or three weeks. Record the weights. At the close of the exercise draw a conclusion as to one of the functions of the covering of fruits. Discuss the reasons for the change of weights in the apples tested.

Note. — Potatoes, peaches, or tomatoes may be used in this Exercise.

CHAPTER XXXIV

MARKETING FRUIT

The increasing cost of production. — The cost of producing fruit is increasing. This is true because land, labor, taxes, interest rates, and transportation are higher than ever before. Also, insect enemies are more numerous and the materials used in combating them are more costly than in former years. For these reasons the producer of fruit must sell his entire crop, and, besides, reduce the cost of marketing as far as possible, if he is to make any money. And money he must make if he is to have a farm and a home.

The increasing interest in marketing. — The production of agricultural products will always remain of great importance; and the marketing of these products efficiently is becoming more important and complex. More than half of our people now live in cities, and a large proportion of them in cities having a population of 50,000 or more. There are almost 200 cities in the United States with a population of over 25,000. The food needs of every man, woman, and child in the United States must be adequately supplied. To trace the route of five things that come to your dinner table would be interesting, and to consider how these different foodstuffs are carried to every one of the 110,000,000 people in our nation is a very complex study. Yet they must all be fed, and fed every day.

Many essentials to successful fruit marketing. — No one knows except the people who are engaged in it how much work there is attached to marketing fruit.

Let us consider the more important steps in the process of

marketing fruit efficiently: (1) careful production; (2) careful picking; (3) careful grading; (4) adequate storage; (5) rapidity in marketing; and (6) proper packing and labeling. These all involve immense labor, risk, and cost in order to get fruit to the consumer.

1. *Careful production.* — Every producer is interested in a good product and is willing to pay for it. Planting only adaptable and hardy varieties of a fruit that will sell is essential. Apple trees require six to eight years to come into bearing. But during this time the orchard must be cultivated, pruned, and sprayed. This cost and the risk are rather great. When the trees begin to bear, additional sprayings are required, sometimes four or five if merchantable fruit is to be produced.

2. *Careful picking.* — This is just as important an operation as any other in fruit production. Apples should not be picked until they have attained a color characteristic of the variety, yet the fruit should not be left on the trees until it becomes soft and mushy. All fruit must be picked by hand. Fruit must not be bruised in picking or in any other operation, and the covering over all fruit should be invariably left on the fruit until the day it is to be sold.

3. *Careful grading.* — Careful grading of fruit has many advantages: (1) Grading saves money for the producer because it costs as much per pound to ship undersized and poor quality fruit as it does to ship good fruit. Besides this, ungraded things sell at a lower price, and this reduces the return to the producer. (2) Careful grading satisfies the demands of the market because the consumer likes to know what he is getting and prefers a uniform product. (3) Care in grading reduces the marketing cost. Apples may be sold by description, trade name, or brand. This enables the producer to sell his product by letter, telegram, or otherwise. This reduces the cost of marketing. Un-

graded apples can be sold only after the personal inspection of the purchaser. This is expensive. (4) Grading increases the price. According to the Bureau of Markets, United States Department of Agriculture, during the three months from September 16 to December 16, about 15 per cent of the apples marketed in Chicago were so inferior that had they not been mixed with good apples they could not have been sold at all. Out of 2600 cars offered for sale, 410 cars were unworthy to be offered. These 410 cars caused a lot of work and their share of freight cost and, besides, reduced the price of the rest of the apples about 25 per cent. (5) Careful grading is the basis for expanding the markets, and expanding the markets is essential if an enlarged output is to be sold at a profit. In a recent five-year period the average production of apples in the United States was 160,000,000 bushels. If there was an average of 120 apples per bushel, then there were about 150 apples per person in the United States per year. This is less than half an apple per person per day. To get these apples to their final destination is difficult and requires that the apples be carefully graded so that present markets may be expanded.

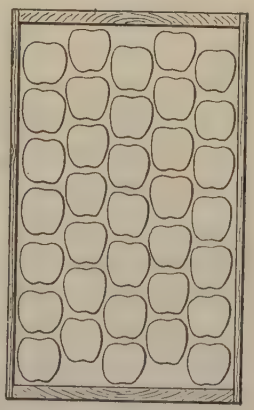


Fig. 213. — A box of apples
Capacity, 175 apples.

6. *Careful packing.* — Boxes for packing apples are of two chief types. The standard box is $10\frac{1}{2}$ x $11\frac{1}{2}$ x 18 inches and has a cubic content of 2173 cubic inches. This box is slightly in excess of one bushel, which contains 2152 cubic inches. The other box is 10 x 11 x 20 inches. There are many different ways of packing apples in the box. Fig. 213 shows how apples are packed.

Most of the best-quality apples are wrapped in paper, and the boxes are lined with paper. This is an additional expense, but it protects the apple and adds much to its commercial value. Packing in barrels is not very satisfactory. A uniform container is helpful in establishing a basis for trade. Farmers' Bulletin entitled "Standard Containers for Fruit and Vegetables," published by the United States Department of Agriculture, which may be had for the asking, gives a full discussion and many illustrations of standard containers. It should be carefully read by those interested in marketing fruits and vegetables.

7. *Proper trade-marks and brands* aid much in selling fruit. A trade-mark should always stand for the same uniform product.

It may be seen from the preceding paragraphs that it requires a lot of work, care, and expense to produce and market fruit which is in good condition and satisfactory to the trade.

Coöperative marketing of fruit. — The California Fruit Growers' Association has marketed most of the fruit of California for a number of years. In 1920 this association marketed for its 10,500 members $57,000,000 worth of oranges, lemons, and grapes. It marketed 74 per cent of the citrus fruits grown in California. In coöperative marketing California is excelled only by Denmark and New Zealand. This association has brought a failing industry into one of reasonable prosperity which is serving the people of the entire nation in supplying them daily with the fruits grown in that section.

The following principles may well be used in any coöperative fruit-selling organization: (1) Market by commodity only. (2) Have contracts with producers so that they will sell their fruit through the association. (3) Sell all fruit on a pool basis. (4) Operate upon a non-profit basis. However, often large savings are made in marketing. (5) Restrict membership to producers; and in voting, the one-man, one-vote rule is of great importance.

Macklin says, "Because farm production is seasonal while consumption is relatively uniform, the annual occurrence of glutting the market is a serious problem." It is this very thing that cöoperative marketing seeks to avoid; and pooling the products is absolutely essential to uniform distribution. Macklin further says, "Pooling of commodities by grades over certain periods of time facilitates the accomplishment of two objects: (1) market feeding and (2) uniform price to producer for the same kind, quantity, and quality of article. In this way hazards in agriculture because of price fluctuations are mitigated."

Hibbard says, "Pooling is an incident in the movement of goods to market, whereby the owners are assured the same treatment and returns corresponding to their contribution of product to the pool, thus obviating speculation."

The California Fruit Growers' Exchange does not fix prices, and it does not sell its products in California alone but sells them as nearly as possible delivered to the consumer. This defeats speculation and helps to stabilize prices of citrus fruits. The money going ordinarily to the speculator is saved to the producer.

The California Fruit Growers' Exchange attempts to market $\frac{1}{52}$ of its output weekly. This is a powerful factor in causing the prices of citrus fruits to be uniform throughout the year. In 1920 the Association had 89 salaried agents in the larger cities of the United States, which helped to prevent the glutting of markets and at the same time maintained a steady and uniform supply where there was a demand for its fruit.

The California Fruit Growers' Exchange sells its fruit under the trade-mark "Sunkist" and through advertising it has increased sales faster than production and good prices have been maintained. Its wonderful marketing system is a great service to all because its products are distributed in a regular, uniform way.

How to expand the market. — Markets may be expanded: (1) by selling a good quality product which is carefully classified and graded; (2) by advertising and indicating the food value of fruit; (3) by organized selling; (4) by careful packing; and (5) by the extension of credit to the growers so that they can market at will, and not be compelled to sell under disadvantageous conditions. The entire commodity must be sold orderly, distributed widely, and never dumped upon the market. Hasty sales result in loss to the producer and to the community, and, hence, careful financing is vital not only to the grower but to the entire group. It is a common practice to extend a credit of from 60 to 80 per cent of the value of the product when in a pool. Final settlement is made at the end of the year or when the entire pool is sold.

Summary. — The cost of producing fruit is much higher than formerly. This is so because land and labor, taxes and interest, transportation, and spraying materials are higher priced. Marketing fruit so that all demands are constantly supplied is a difficult matter. And to produce good fruit and then to distribute it well are big tasks.

Coöperative marketing based upon a well-graded, quality product and upon a single commodity and upon a distribution over the widest possible area consistent with demands and costs of marketing is very helpful in making savings for the producer, and hence in making him prosperous. Individual prosperity leads to community prosperity; and if every community and section is prosperous, it will lead to national prosperity.

There should be one word of warning about coöperative marketing. It is a good plan but the plan will not work itself. The plan must be worked if it is to be successful. Such books as Macklin's "Efficient Marketing for Agriculture" and Powells' "Coöperation in Agriculture" set forth the essentials of coöperative marketing.

CHAPTER XXXV

HARMFUL INSECTS AND HOW TO CONTROL THEM

Definition of insect. — Insects have jointed bodies with three distinct parts: head, thorax, and abdomen. They have compound eyes, one pair of antennæ, known as feelers, three pairs of legs, and two pairs of wings. Most insects have four stages in their life history; this metamorphosis consists of the egg stage, the larva, or caterpillar, stage, the pupa, or cocoon, stage, and the adult stage. Let us briefly illustrate the parts, or anatomy, of insects and their life history, or metamorphosis.

Fig. 214. — A grasshopper

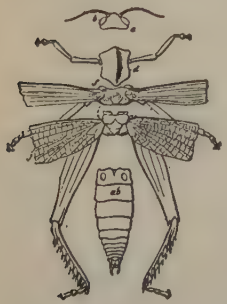


Fig. 215. — A grasshopper dissected

The grasshopper is a typical insect, having all the parts (Figs. 214, 215).

On the head we find compound eyes, a pair of feelers, and two strong, biting mouth parts. On the thorax there are six legs and four wings. The abdomen consists of ten rings, or segments. On each segment there is an opening through which the grasshopper breathes.

Cabbage worms (Fig. 200) illustrate the

metamorphosis, or life history, of insects. The cabbage worm comes from an egg laid by the cabbage butterfly, which is really a moth. (A moth flies at night and does not fold its wings over its back as butterflies do.) From the egg stage it passes into the larva stage, which is the cabbage worm. The next stage is the pupa stage, through which the worm changes, or metamorphoses, into the adult stage. This stage may be produced by placing a cabbage worm in a fruit jar and feeding it until it goes into the pupa stage. During the pupa stage it does not eat. This is apparently a resting stage, except for growth. Then the pupa passes to the moth, or the adult, stage.

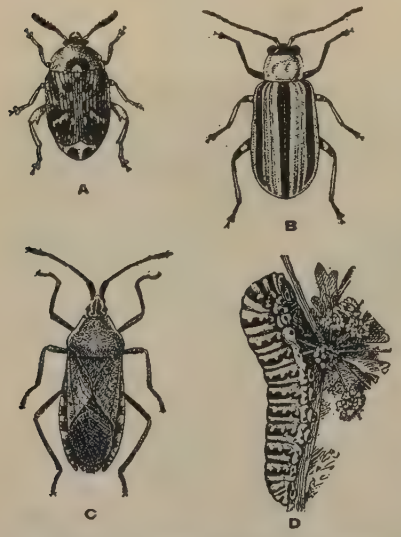


Fig. 216. — Insects injurious to gardens

A, pea weevil; B, cucumber beetle; C, squash bug; D, celery caterpillar (the larva of the black swallowtail butterfly).

Insect depredations. — Insects lay a heavy toll, or tax, on plant growth every year. Many observers say that the average damage will equal ten per cent of the value of all farm crops. Each pupil can doubtless give illustrations of the insects he has had to combat at home and of the loss that has been sustained from the depredations of insects. There are insects of the garden, orchard, field, household, and storage room, as well as insects that prey upon animals. To discuss all of these would require volumes. But a few we may suggest in the following form:

(1) *Garden.* — Cabbage worm, Colorado potato beetle, ant, cabbage maggot, onion maggot, cutworm, grasshopper, striped cucumber beetle, and white potato grub. (See Figs. 158, 200, 214, 216.)

(2) *Orchard.* — Round-headed and flat-headed apple-tree borer, peach-tree borer, San José scale, gypsy moth, apple-leaf folder, peach-leaf folder, codling moth, plum gouger, peach curculio, and grape curculio. (See Figs. 207, 208, 210.)

(3) *Field.* — Corn-root worm, cornstalk borer, bill bug, joint worm, Hessian fly, cutworm, alfalfa-leaf weevil, army worm, cotton-boll weevil, and corn-ear worm. (See Figs. 66, 95, 169, 170, 171, 220.)

(4) *Household and stored products.* — House fly, mosquito, house ant, roach, flea, bedbug, clothes moth, grain weevil, and bean weevil. (See Figs. 217, 219.)

(5) *Domestic animals.* — Horse bot fly, sheep bot fly, ox-warble, cattle tick, lice, and mites.

No one can know with accuracy the damage insects do. Every crop makes good food for insects, and there is not a plant that has not one or more insect enemies.

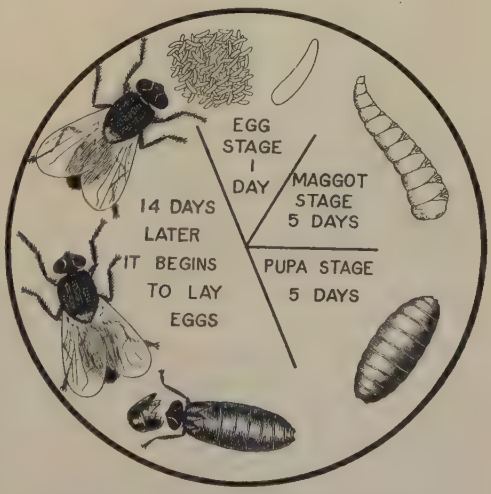


Fig. 217. — Life history of the house fly

Insects carry human diseases. — The house fly is an insect; for, although you may think that it has only two wings, upon close examination you

will find four. House flies carry typhoid fever, tuberculosis, and other bacterial diseases. They incubate in stable manure and other places of filth. If all litter is taken away weekly and scattered in garden or field, the breeding places of flies will be destroyed and they will have little chance for propagation. Swatting flies and the use of flytraps and fly-paper all help to reduce their number. Flies may also be killed by adding two tablespoonfuls of 40 per cent formalin to one pint of sweet milk and putting this in shallow pans. A piece of bread placed in the solution will assist, for it gives flies a better chance to alight and feed.

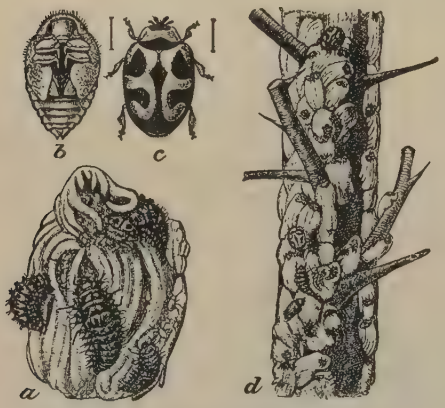


Fig. 218. — Australian ladybird beetle and fluted scale

a, larvæ of beetle feeding on scale; *b*, pupa; *c*, adult; *d*, orange twig showing scales and beetles.

Mosquitoes are of many kinds, but in one respect they are all alike; namely, they all have their immature stage in stagnant water. A tin can, a water trough, or a rain barrel may incubate thousands. The best way to combat mosquitoes is to destroy their breeding places by eliminating all stagnant pools or stagnant water of any kind. Mosquitoes, like flies, unless carried by winds will not get more than a half mile from their breeding place.

Malaria fever depends for a part of the cycle of its life upon a certain species of mosquito. The mosquito becomes infected with the malaria-fever germ by sucking the blood from a malaria patient. Then the germ is carried by the mosquito to another

person. Yellow fever is also transmitted by a certain kind of mosquito.

Preventing insects. — Insects have several natural enemies. One insect often becomes an important enemy of another. The ground beetle, tiger beetle, and ladybird beetle are all destroyers of insects. There are, of course, other insects that destroy insects. Fig. 218 shows one of nature's ways of keeping a balance in insect life.

Birds rank first as destroyers of insects. Few of us appreciate the large number of these pests destroyed by birds. In fact, birds depend upon insects to furnish them with a large part of their food. And when the earth is covered with snow or ice, often many birds perish because they are unable to get weed seeds or insects. During such a time a little help from people in feeding birds will greatly aid in maintaining the bird population. Among our best bird friends are the swallow, kingbird, catbird, robin, bluebird, woodpecker, chickadee, and cardinal. Hawks and owls depend almost wholly on insects and seeds for their food. Over thirty different kinds of insects are known to be the food of hawks and owls. The quail too is the farmer's friend. Chinch bugs and other insects are eaten by quails.

Fig. 219. — Injury done by bean weevil to stored beans

In a recent survey made by the United States Department of Agriculture it was found that the stomachs of birds con-

tained the following insects and seeds and that birds pay well for their board and lodging.

1 Flicker	28 white grubs
1 Nighthawk	34 May beetles
1 Grackle	100 cotton bollworms
1 Killdeer	300 mosquito larvæ
1 Tree swallow	30 chinch bugs
1 Pheasant	8000 seeds of chickweed and dandelion
1 Duck	72,000 weed seeds
1 Bobwhite	1700 weed seeds
1 Yellow-billed cuckoo	217 fall webworms

Aside from protecting birds, man may do much to prevent insect pests. Rotation of crops is an important way to prevent insects. Many insects attack only one kind of plant. Thus the enemies of cotton do not attack the corn plant, and vice versa. The insects of wheat seldom bother clover or the legumes. Therefore rotation of crops does much to destroy them.

From Watts' Vegetable Growing Projects

Fig. 220. — Injury by corn-ear worm

Fall plowing destroys many insects. Insects harbor for the winter in the rubbish of the field; but when this is plowed under, the eggs and pupæ of insects are exposed, and many of them perish.

Cleaning fence corners, destroying weeds, and keeping the garden, orchard, and field clean will do much to eradicate them.

Changing the time of planting will often avoid their ravages. The Hessian fly is thus largely avoided. Planting potatoes, corn, cabbage, and other crops early will partially evade the large broods of insects. The thing to do is to study the insect pests and then beat them at their own game.

Poultry, turkeys, and geese destroy many insects. In fact, farmers may affect a saving in protein feeds for chickens and turkeys, if these fowls can find a good crop of grasshoppers and other insects.

Use of sprays. — More than 350,000 insects have been described by scientists, and according to the best authorities there are at least as many more not yet classified. But this vast array of insects have only two ways of getting their food. They either get it by sucking or by biting and chewing. Therefore in this lies the entire secret of insect control. Biting insects are killed by stomach poisons, and sucking insects are killed by contact sprays.

1. *Biting insects.* — All biting insects have biting mouth parts used in biting or chewing the vegetation upon which they subsist. Fig. 219 is representative of the eating habits of this class of insects.

The army worm, potato bug (Colorado beetle), cabbage worm, striped cucumber beetle, various cutworms, blister beetles, and grasshoppers are examples of biting insects. All of these insects are combated by a poisonous insecticide, such as arsenate of lead or Paris green.

2. *Sucking insects.* — Sucking insects have a long sucking mouth part (proboscis) and can draw their foods from the stem or leaf of the plant without taking the poisons sprayed on the surface of plants. For these a contact spray must be employed.

All plant lice, aphids which attack flowers and fruits, and the San José scale are sucking insects. Contact insecticides must be employed to destroy them.

Insecticides. — Insecticides are of two kinds; namely, stomach poisons for biting insects and contact sprays for sucking insects.

1. *Stomach poisons.* — Arsenate of lead is the most common and the most authoritatively recommended stomach poison. However, Paris green is occasionally used. Arsenate of lead has the following advantages over Paris green; it adheres to the foliage better and longer, mixes with the water solution more satisfactorily, is just as deadly, and is usually cheaper and does not burn foliage.

Arsenate of lead spray is made as follows:

Arsenate of Lead

Arsenate of lead, 3 to 5 pounds (paste)
or
Arsenate of lead, 2 to 3 pounds (powder)
} to 50 gallons water.

Paris green spray is made as follows:

Paris Green

Mix 2 pounds Paris green to 50 gallons of water.

Arsenate of lead in smaller quantities is made by mixing 3 tablespoonfuls of arsenate of lead to 1 gallon of water. The powdered form of lead arsenate is handled much more easily than the paste and is therefore recommended.

2. *Contact sprays.* — Self-boiled lime-sulphur is one of the best contact sprays and is used for the brown rot.

To make this spray slake eight pounds of quicklime in two or three gallons of water, and while the lime is slaking sprinkle the powdered sulphur into it. Stir constantly while slaking. Dilute to 50 gallons of water. Strain before using. It requires about an hour to make the solution. Its composition is as follows:

Self-boiled Lime-Sulphur

Quicklime	8 to 10 pounds
Sulphur	8 to 10 pounds
Water	50 gallons

The dormant spray used for the San José scale has about three times the strength of the above spray (Fig. 209).

Kerosene emulsion is also a good contact insecticide. It is especially effective for the control of plant lice and aphids. It is made as follows:

Kerosene Emulsion

Hard soap	½ pound
Hot water (soft)	1 gallon
Kerosene (coal oil)	2 gallons

Dissolve the soap in hot water by boiling, and when it is dissolved add the kerosene.

Commercial tobacco extract, tobacco dust, and Black Leaf 40 are valuable repellents and contact sprays. These may usually be had directly from tobacco factories or drug stores.

Bordeaux mixture is used for the prevention and control of fungous diseases such as apple scab, potato blight, and leaf spot on tomatoes, and for soft-bodied sucking insects. Bordeaux mixture is made by dissolving four pounds of copper sulphate in about two gallons of water, and slaking four pounds of lime in a separate vessel of two gallons of water. Fig. 221 illustrates the method of making the copper sulphate and lime solutions.

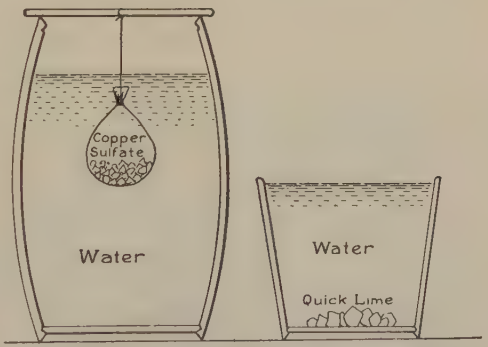


Fig. 221. — Making Bordeaux mixture

Copper sulphate and lime are dissolved in separate vessels of water for 24 hours; then they are poured together, and water is added till the solution is reduced to the desired strength.

The copper sulphate is suspended in a cloth in the water for 24 hours. The lime is likewise slaked in a separate vessel for about 24 hours. Then the solutions may be mixed and sufficient water added to make 50 gallons of the solution. The copper sulphate solution and the lime solution should not be mixed until the day upon which they are to be used. The spray is known as a 4–4–50 Bordeaux mixture spray.

Complete sprays. — A complete spray will combat both insect and fungous enemies. If, for illustration, apples are sprayed for both the codling moth and apple scab, then the regular arsenate of lead spray plus the Bordeaux mixture will combat both enemies. However, the water used in making the Bordeaux mixture must not be used in the complete spray unless all chemicals are doubled. Likewise potatoes may be sprayed with the regular arsenate of lead for the Colorado beetle, and if Bordeaux mixture is added it will also combat the potato blight. If sucking and biting insects and fungous enemies all are on the plant, such spray materials must be compounded to destroy each enemy. Making and using complete sprays saves labor.

Spray Calendar

Crop	Insect	Proper Time to Spray	Insecticide
Potatoes, Tomatoes	Colorado potato beetle	As soon as signs of insect appear.	Arsenate of lead, three tablespoonfuls to 1 gallon of water.
Cabbage	Cabbage worm	As soon as signs of insect appear and about 10 to 14 days thereafter.	Same as for potato bug, plus making the water soapy.
Cucumber, Melons	Cucumber beetle	As soon as injury appears.	Same as spray for cabbage worm.
Almost all garden crops	Blister beetle	When the beetles appear.	Arsenate of lead. $2\frac{1}{2}$ pounds of powder to 50 gallons of water.

SPRAY CALENDAR—*Continued*

CROP	INSECT	PROPER TIME TO SPRAY	INSECTICIDE
Cabbage, Radish, Turnips	Harlequin cabbage bug	When the insect appears.	Kerosene spray. ½ pound laundry soap, 12 gallons water, and 2 gallons of kerosene.
Cucumbers, Melons, Cantaloupes, Squashes	Squash bug	When the bug appears.	Use the above kerosene spray.
Flower and garden crops	Aphids or plant lice	When the lice are first seen. Repeat every three to five days.	Kerosene emulsion. 5 per cent solution, or 1 gallon kerosene to 12–15 gallons water, plus 2 pounds soap; or Black Leaf 40.
Apples	Codling moth	Just before trees bloom. When blooms drop off, and every 3 to 5 weeks thereafter.	Arsenate of lead. 2 pounds to 50 gallons water.
Apples	Apple blotch and apple scab	Same as for codling moth.	Bordeaux mixture, 4–4–50.
Potatoes	Blight	When plants are well up and about every 10–14 days thereafter.	Bordeaux mixture. Bordeaux mixture plus arsenate of lead for beetles and blight.
Tomatoes	Tomato leaf spot	Before disease appears and repeat at 10-day intervals.	Bordeaux mixture.
Peaches	San José scale	Early spring before the leaves appear. Known as a dormant spray.	Boiled lime–sulphur spray.
Peaches	Brown rot, peach scab	When blossoms have fallen. Again three or four weeks later.	Self-boiled lime-sulphur spray.
Grapes	Black rot	Spray when third leaf appears; again when blooms open; and twice later at intervals of 2 to 3 weeks.	Bordeaux mixture.
Plums	Plum curculio	When petals begin to fall.	Lead arsenate spray.

Spray machinery. — Spray machinery ranges in size from small hand atomizers to large power sprays. The hand spray may be used on flowers and other plants where only a small amount of spraying is to be done. In case orchards are to be sprayed a larger spray must be used (Fig. 209).

Repellents. — Some insects may be driven away by repellents; that is, by chemicals and other substances offensive to them. The striped cucumber beetle may be driven away by dry slaked lime. This is prepared by placing a fresh lump of lime in a vessel and then slowly adding hot water. The lime will slake to an extremely fine powder. This is dusted on the insects and around the plants.

Tobacco dust is fairly effective as a repellent. It is dusted on the insects, and for root maggots the dust is heaped around the stems of the plants.

Naphthaline or moth balls will repel clothes moths and some of the pests that infest dried animal products. If moths have already laid their eggs on garments, no benefit will be derived from naphthaline, for it does not affect the larvæ, being a repellent only for adults.

Fumigants. — Only air-tight places, such as greenhouses, wheat bins, or boxes may be fumigated. All kinds of weevils that infest stored grains are combated with carbon bisulphide. One pound of carbon bisulphide should be used for each 100 cubic feet in the fumigating chamber. If grain is fumigated, one pound of the liquid should be used to 100 bushels of grain. The liquid should be placed in shallow dishes and allowed to stand in the enclosed chamber for at least 24 hours. One precaution should be observed: no fire should be permitted anywhere near at the time of fumigating.

Sulphur is an excellent fumigant for some things. Two pounds of sulphur in a small vessel, placed in a large fireproof

vessel, should be ignited to furnish fumes in the enclosed room or chamber for 24 hours. As a means for killing bedbugs, poultry lice, or mites it is excellent.

Hydrocyanic gas is a deadly poison and should be used only by those who have had experience. It should not be used in a house unless the entire premises can be vacated for three or four days. This fumigant is so poisonous that it will kill plants; but when greenhouses are cleared of crops, valuable protection may be secured for succeeding crops.

For the control of plant lice in greenhouses, tobacco is an excellent fumigant. The usual method is to burn the tobacco stems or dust. The tobacco smoke is deadly to plant lice. Liquid tobacco-stem extract may be vaporized and the vapor used as a fumigant with excellent results.

Summary. — There are insect enemies of every plant grown, and the loss sustained from insects is estimated to be about ten per cent of the value of the crops. There is much money spent for the prevention and control of insects. If insects can not be controlled by ordinary methods, then we should resort to sprays. For sucking insects contact sprays should be used; for biting insects, poison sprays. In some cases it will require community action to control insect depredations.

LABORATORY EXERCISES AND HOME PROJECTS

1. Examine and dissect a grasshopper. Draw the three parts of the body; draw the antennæ, the wings, the parts of the legs, and the feet. Draw the mouth parts.

2. Answer these two questions: (1) What sprays would you use for the Colorado potato beetle, tobacco worm, army worm, and cabbage worm? (2) What spray would you use for the San José scale and plant lice?

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